HUMAN CAPITAL, CONVERGENCE, AND INCOME INEQUALITY: A LATENT VARIABLE APPROACH

By

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I dedicate this dissertation to my parents, Mahalakshmi and Krishna Murthy Duvvuri. Without their encouragement, blessings, and high expectations I could not have attained this level of education.

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Convergence in income and its determinants, for 22 OECD countries during 1955-1990, was analyzed using a latent variable approach and via Theil's inequality index. Income was specified as a function of human capital, international openness, government expenditure, and investment expenditure drawing on the theoretical underpinnings from standard macroeconomic theory and from recent developments in economic growth theory. Human capital, which cannot be observed directly, was treated as a latent variable. Theil's inequality index was computed for income and its determinants.

The latent variable model was estimated using maximum likelihood. The results of this estimation showed that the effects on income levels, of human capital, international openness, investment expenditure, and government expenditure were statistically significant and positive. Human capital had the greatest positive effect

indicating that it was a key determinant of income levels for the OECD countries. Further, all the determinants were increasing over time at an average per capita level.

Estimated income per capita and Theil's income inequality index were computed using the estimated human capital, the other three determinants and the parameters of estimation. The results of these computations indicated that the estimated income fitted the observed income closely and that both the observed and estimated incomes were increasing during 1955-1990.

Theil's inequality index was then used to measure observed and estimated inequalities in income, human capital, international openness, investment expenditure, and government expenditure. The evidence from the income inequality analysis is in favor of the convergence component of Kuznets' hypothesis. Further, the analyses of the inequalities in income, human capital, openness, investment and government expenditures revealed that the OECD countries, as a group, were moving closer in terms of income, openness , and government expenditure. However, these countries are diverging in terms of human capital and investment expenditure.

CHAPTER 1

INTRODUCTION

Since the time of Adam Smith (1937) varying rates of economic growth have puzzled economists; thus, for the past several decades this issue has been the focus of research for economists. Three salient and apparent features of studies on economic growth are (a) long-run growth of per capita income has been sustained at a positive rate for many countries; (b) rates of growth vary across countries; and (c) methodologies vary for measuring and explaining economic growth and disparity. The principal question asked was whether countries varied greatly in their growth rates and whether these differences were the outcome of random processes. Further, the phenomenon of accelerated growth of poorer economies causing them to "converge" in per capita income level with that of the richer economies and the factors affecting this growth have become the focus of developmental and international economists.

By convergence we refer to the process of the faster growth of relatively poor countries to enable them to "converge" with the growth of relatively rich countries. The divergence-convergence hypothesis originated in neoclassical economics with Kuznets' inverted-U theory (1955) which states that, in the process of economic development, inequality within a country initially increases in the early stages, stabilizes at some peak level, then declines as the latter stages of development occur (divergence followed by

convergence). Though Kuznets studies income inequality within an economy, the implications of his theory have led to many studies testing Kuznets' hypothesis across countries.

From the survey of recent literature on convergence and income inequality, four types of studies have emerged: those that measure income inequality directly (Wright, 1978; Bornschier, 1983; Branco and Williamson, 1988; Theil, 1989; Berry et al., 1991; Oshima, 1992; Ram, 1992; Theil and Deepak, 1993a, 1993b, 1993c, 1994; Moss et al., 1993; Seale et al., 1994; Theil and Seale, 1994), those employing regression analysis (Ram, 1988, 1989a, 1989b; Barro, 1991; Barro and Sala-i-Martin, 1992; Mankiw et al., 1992), those based on growth models (Lucas, 1988, 1993; Rebelo, 1990; Tamura, 1991; Glomm and Ravikumar, 1992; Romer, 1994), and those using time-series techniques (Weatherspoon, 1993; Weatherspoon et al., 1994).

This survey shows that there is evidence that, in terms of income inequality, rich countries are converging, poor countries are diverging, and the level of affluence increases with increasing distance from the equator (Theil, 1989; Seale et al., 1994; Theil and Deepak, 1994; Theil and Seale, 1994; Moss et al., 1993). However, till recently, though researchers have failed to reject the Kuznets' hypothesis to a large extent, they failed to define, with any certainty, the determinants of convergence (or divergence).

Of those that have analyzed or explored the determinants of convergence, Barro (1991), Barro and Sala-i-Martin (1992), and Mankiw et al. (1992) found, empirically, that human capital tended to be an important factor in determining convergence. Lucas

(1988, 1993) also concluded that, with the inclusion of human capital in the production function, an economy with a human capital stock lower than the world average would grow faster than an above average economy. Tallman and Wang (1992), reviewing studies using theories of neoclassical and endogenous growth, concluded that accumulation of human capital yielded positive dividends in terms of income and thus standards of living.

This study expands on the above mentioned research and attempts to explain the process of convergence (or divergence) via factors that influence economic growth. While Weatherspoon (1993) used cointegration analysis to test for a long-term relationship in inequality among income, investment and government expenditures, and industrial employment, this study uses the latent variable model approach to analyze convergence in income levels and via directly measuring income inequality using Theil's (1989) inequality index.

Specifically, per capita incomes (determined by per capita levels of human capital, international openness, investment and government expenditures) for 22 member countries of the Organization of Economic Cooperation and Development (OECD) (USA, Canada, Japan, Austria, Belgium, Denmark, Finland, France, West Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, UK, Australia, New Zealand) were estimated via a latent variable model (Bollen, 1989) with human capital as the latent variable. An inequality index as derived by Theil (1989) was then used to measure the inequality in per capita income and its

determinants. The results from the above computations were used to analyze the effect(s) of determinants of growth on patterns, if any, of convergence (or divergence).

The next chapter gives a brief overview of existing evidence on convergence (or divergence). The literature is divided into four groups: studies using inequality measures, studies using regression analysis, studies using models of economic growth, and studies using time-series analysis. By and large, the studies using inequality measures and time-series analysis failed to reject Kuznets' hypothesis, while the studies using growth theories either rejected or were inconclusive in testing the inverted-U hypothesis. The regression studies show some evidence in support of convergence-divergence hypothesis.

Chapter 3 deals with the data used for the analysis of this study and includes a description of the compilation of purchasing power parity data by Summers and Heston (1993) in forming the Penn World Table (Mark 5). This chapter also details the other two sources of data: Statistical Yearbook, UNESCO (1963-1993), and Basic Facts and Figures, UNESCO (1951-1962) for compiling information for the indicators of human capital in the 22 OECD countries (two countries from Asia [Japan and Turkey], two from the Western Pacific Rim [Australia, New Zealand], 16 from Europe [Austria, Belgium, Denmark, Finland, France, Greece, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and UK], and two countries from North America [USA and Canada]).

Chapter 4 presents the generalized latent variable model (Bollen, 1989), and tabulates the results of estimation of per capita income. The chapter concludes with a brief study of the patterns in observed and estimated per capita incomes and the

explanatory variables for the 22 OECD countries. These trends are then compared and contrasted with evidence from literature.

Chapter 5 describes Theil's inequality index and presents the computations of inequalities using income, human capital, international openness, investment and government expenditures. The patterns of convergence (if any) are studied and analyzed. These results are also compared and contrasted with evidence from past studies. Chapter 6 summarizes and concludes the study.

CHAPTER 2

EVIDENCE OF CONVERGENCE

The interest in studying convergence has been derived from the basic relationship between development and income distribution. To achieve convergence the poorer countries need to increase their productivity at a rate greater than that in richer countries (Barro and Sala-i-Martin, 1992). The importance of the pattern of income distribution during various stages of development and the lack of adequate time-series data for most developing countries culminated in many studies which attempt to test Kuznets' hypothesis with varying methodologies. The predominant methodologies used include inequality measures (Theil, 1989; Berry et al., 1991; Oshima, 1992; Ram, 1992; Moss et al., 1993; Theil and Deepak, 1993a, 1993b, 1993c, 1994; Theil and Seale, 1994; and Seale et al., 1994), regression analysis (Wright, 1978; Bornschier, 1983; Branco and Williamson, 1988; Ram, 1988, 1989a, 1989b; Barro, 1991; Barro and Sala-i-Martin, 1992; Mankiw et al., 1992), theories of growth (Lucas, 1988, 1993; Rebelo, 1990; Tamura, 1991; Glomm and Ravikumar, 1992; Romer, 1994), and time-series analysis (Weatherspoon, 1993; Weatherspoon et al., 1994).

Since the recent developments in endogenous economic growth research (Romer, 1989), growth in income is no longer treated as a random process but as something that is systematically related to other factors in the economy (Grossman and Helpman, 1991).

Summers and Heston (1988) plot the growth rates of 114 countries between 1960 and 1985 against the level of per capita income in 1960. This plot did not depict any strong correlation between initial levels of income and growth during the period, but revealed the variation in growth rates between countries. In the past, growth patterns in the world could not be studied effectively due to data constraints. But the Penn World Table (PWT) time-series data for various economic indicators compiled by Summers and Heston (1991) have changed the scenario to a large extent.

2.1 Studies Using Inequality Measures

The simplest inequality measures are estimates of statistical dispersion like variance, standard deviation, and the coefficient of variation. A commonly used inequality measure is the gini coefficient which is based on the Lorenz curve (Anand and Kanbur, 1993). This statistic measures the ratio of the area between the diagonal and the Lorenz curve to the total area below the diagonal. Another measure is the Theil entropy index (also known as Theil's inequality index) which measures inequality by taking the logarithm of the ratio of the arithmetic mean income to the geometric mean income. The appropriateness of the inequality index to be used depends on the objective of the study as well as the properties of the index (Chapter 5, Section 5.4). For example, Theil (1989) used a decomposable inequality index to better assess its behavior internationally as well as regionally.

Theil (1989) used the Summers and Heston (1988) data set spanning 1950-1985 to assess the economic development in five regions of the noncommunist world: the

North consisting of 25 countries (U.S. and Canada from the American continent, Japan and Korea on the Western Pacific Rim, and 21 countries in Western and Southern Europe), the South with 9 countries (Argentina, Chile, and Uruguay from the Southern Cone of the American continent, Australia and New Zealand on the Western Pacific Rim, and South Africa, Botswana, Lesotho, and Swaziland from the Southern tip of Africa. He measured income inequality as the natural logarithm of the ratio of arithmetic mean income to geometric mean income which was additively decomposable. He concluded that international inequality increased substantially from 1960 to 1980, and that regional inequality dominated the average within-region inequality. In 1960 the inequality in the North exceeded that in any other region, but Northern inequality declined very rapidly so that it was second lowest in 1985. In contrast to the North, Tropical Africa and Asia showed substantial increases in inequality.

Berry et al. (1991) conducted an extensive analysis on world income inequality. They analyzed over 100 countries during 1950-1977. They used data from World Bank Tables (1976, 1980a), World Bank Atlas (1988), World Development Report (1980b, 1987, 1988), and the Summers and Heston (1988) data set. They computed Theil's entropy index, Atkinson's inequality, and the Gini coefficient. The major difference in their study was that they computed inequalities for gross national product (GNP) and consumption measured as a percentage of GNP to study changes in welfare. The underlying logic being that the distribution of consumption was less unequal across countries and the savings rate was below average for the poorer countries. Berry et al. (1991) contended that marginal propensities to consume decrease with decreasing income

and, therefore, lower savings rates in poorer countries contributed to greater inequality worldwide. They also conducted similar analyses with and without the nonmarket economies which showed that inequality in the world began increasing in the mid-sixties and continued increasing until 1986. In addition, they divided the world's inequality into deciles and showed that the income shares of the bottom half remained unchanged while the top decile gained at the expense of the sixth, seventh, and eighth deciles.

Oshima (1992) tested the Kuznets hypothesis for the Asian countries. He found that though there is an upward and then a downward trend in income inequality in most Asian countries, the peak in the trend appears much earlier in the stage of development in Asia than in the West. In Asia, the peak is reached when the economy is still predominantly agricultural with per capita incomes much lower than in the West where the peak was reached when the economy was predominantly industrial. Hence, the forces and mechanics underlying Asian trends are different from the West, although those underlying Japan's trends are similar to those of the West. He concluded the reason for this difference is that Asia (with the exception of Japan) never went through the first industrial revolution of the 19th century.

Ram (1992) used an inequality index, prescribed by Bourguignon (1979), to measure the regional and interstate income inequalities in the United States. The data mainly consisted of the U.S. Bureau of Economic Analysis (1989a, 1989b, 1990) estimates of state personal income per capita and total personal income. The data were available from 1950 through 1989 and covered 50 states (including Alaska and Hawaii and 48 others) and District of Columbia. He found that interstate income inequality,

though small in magnitude, traced along with the U-shaped profile propounded by Kuznets. Further, a simple quadratic form in terms of time fitted the data extremely well. Inequality indices for 1977 and 1988 were computed after adjusting for interstate price-level changes. These revealed large reductions in the indices and a virtual disappearance of the increase in inequality after 1978. A decomposition of the index showed that income changes accounted for most of the inequality change in each decade. Lastly, the six most influential states in terms of their impact on interstate inequality were tabulated for 1950, 1959, 1969, 1979, and 1989. Three of these states had below average income and three had above-average income. New York and California from the above-average group and Alabama and Mississippi from the below-average group contributed the largest components to interstate inequality.

Moss et al. (1993) used the Summers and Heston (1993) data to analyze income changes in the G-7 countries (USA, Canada, Japan, UK, West Germany, France and Italy), for the period 1950 to 1988, using Theil's measure of income inequality. They found that for the G-7 as a whole, per capita GDP increased almost threefold in that period, while the inequality among the seven countries declined dramatically. They concluded that Japan's increasing affluence toward European levels was the reason for this dramatic decline in inequality. The income inequality among the G-7 countries declined almost uninterruptedly. Since the G-7 can be viewed as affluent, this evidence is in favor of convergence.

Theil and Deepak (1993a, 1993b, 1993c, 1994) used Theil's inequality index to measure income inequality across countries and regions during the period 1950-1990.

Firstly, they categorized 113 countries into seven regions--North, South, Tropical Africa, Tropical America, South-East Asia, South-Central Asia, South-West Asia (see Appendix A for countries within each region)--for the period 1950-1990. They found that the North was converging, South-East Asia was diverging, South-Central Asia presented no evidence of convergence or divergence, and the inequality values of sub-Saharan Africa tended to increase from the mid-1960s until the late 1970s and to decline thereafter--a pattern in favor of the Kuznets hypothesis. Secondly, they compared the inequality in Western Europe, Mediterranean Europe and Mediterranean Africa; South Africa and its neighbors; USA, Mexico, and Central America; the Southern Cone of South America and its neighbors (Appendix B). The results indicate a strong tendency toward more poverty when moving from temperate zones toward the Equator. Thirdly, they considered three regions in Western Europe consisting of 18 countries--non-EU, EU Center, and EU Periphery (see Appendix C for countries within each region)--and found that the income inequalities in the regions of EU and EU Center declined by more than 90%. This result was also in favor of convergence. In the case of the EU Periphery, the first 20 years provide evidence of transition from divergence to convergence. Lastly, they considered 15 noncommunist countries (Appendix D) in the Western Pacific and found that there was a strong tendency to greater poverty in movement toward the Equator from the temperate zones in the North or South.

Theil and Seale (1994) used the purchasing power parity (PPP) based data for gross domestic products to assess the affluence of more than 100 non-communist countries in 1950-1990. A seven-region classification, based on the distinction between

temperate and tropical zones, is used to summarize the data on individual countries. The seven regions account for nearly 90 percent of the inequality among these countries in each year. Another classification, based on the position of countries with respect to the European Union, is applied to 18 countries in Western Europe. Five journeys around the world were described; the main result was that affluence tended to decline when the traveler moved from temperate zones (in either the Northern or the Southern Hemisphere) toward the Equator. Another topic considered was that of the G-7 countries, the populations of which are all concentrated in the temperate zones of the Northern Hemisphere. Also, attention was paid to Kuznets' hypothesis of divergence-convergence in a cross-country context.

Seale et al. (1994) relate regional growth and the inequality across countries for four regions of the noncommunist world: the North, Sub-Saharan Africa, South-Central Asia, and South-East Asia (Appendix E). Their results indicate strong convergence in the North and strong divergence in South-East Asia, whereas the case of South-Central Asia is unclear. In the case of Sub-Saharan Africa, there is growth with divergence, in agreement with Kuznets hypothesis, but thereafter negative growth with convergence, which is a digression from the hypothesis.

2.2 Studies Using Regression Analysis

Wright (1978) examined the validity of Kuznets' hypothesis versus the institutionalist hypothesis. The institutionalist hypothesis states that institutional structures and government policies are the chief determinants of income inequality.

Wright used a gini coefficient inequality measure to calculate the inequality in GDP per capita among 56 countries. He concluded that the cross-sectional data demonstrated that (1) inequality varies among countries at all levels; (2) variation in and level of inequality are higher among LDCs; and (3) an institutionalist variable in regressions explains far more income variation among countries than income levels. Further, the divergence-convergence hypothesis lends itself to the conservative argument that redistribution is growth reducing, while growth itself will take a country to the declining side of the "parabola of skewness" more quickly. In the institutionalist view, reduction in inequality depends on modifications in the institutions and policies which generate it.

Bornschier (1983) outlined explanations of international differences in personal income distribution that were formulated within the "world economy" and the "level of development" paradigm. He constructed the Gini index of personal income inequality for 72 countries using Ballmer-Cao and Schiedegger (1979) data. He concluded that income inequality does not vary directly with development, but with surplus, power and the structural position within the world economy. Thus less developed countries do not automatically decrease their inequality in the process of development.

Ram (1988) studied the validity of Kuznets' hypothesis by extending his study to cover several countries. His hypothesis stated that intercountry inequality across nations would first increase with secular economic growth, then start to decline at some point. His sample consisted of 32 countries (24 less developed countries (LDCs) and 8 developed countries (DCs)) which were market economies from the Summers and Heston (1984) data. Average per capita world GDP was used as a proxy for the level of

development and Theil's income inequality measure was used to study income inequality. In addition, Ram used a Kuznets type quadratic regression to determine the relationship between the level of income and development, which represents development and inequality. The equation is

$$J_t = b_0 + b_1Y_t + b_2Y_t^2 + u_t$$

where J is the measure of world inequality and Y is the natural logarithm of the average real GDP per capita. The last term is the disturbance term assumed to have the standard properties for best linear unbiased estimates. Ram found that the hypothesis was well supported when both LDCs and DCs were included in the sample and there is very little support when only LDCs were considered.

Branco and Williamson (1988) also tested Kuznets' hypothesis by analyzing development and income distribution. This study was unique in that it developed an absolute per capita income measure for the poorest 40% of the population in 68 countries. Their measure was the percent of income of the poorest 40% of a nation's population in 1970 divided by 40% of the 1970 population, then multiplied by the real per capita GDP of that nation in 1970 (Summers and Heston, 1984). Their findings suggested that the poorest 40% of the population lose income both relatively and absolutely in the early stages of economic development; thereafter, there are gains in income although with diminishing marginal returns at the highest levels of development.

Ram (1989a) also extended his 1988 study to the world economy inclusive of 115 market economies drawn from the Summers and Heston (1984) data for the years 1960-1980. Using the same structure of the model as before, found that though world income

inequality increased since 1960, there was a noticeable deceleration in the rate of increase of inequality.

Ram (1989b) attempted to study the effect of education on income inequality in LDCs. Firstly, upon reviewing the literature in this area he found contradicting evidence of the influence of education on inequality. Chiswick (1971, 1974), Chiswick and Mincer (1972), Chenery and Syrquim (1975), and Ahluwalia (1976) contended that education did influence income inequality, while Fields (1980), Psacharopoulos and Woodhall (1985), and Morrisson (1987) concluded that there was no clear evidence that education had an effect on income inequality. These contradictory results prompted Ram to conduct his study using two sets of data that yielded contradictory results. His study concluded that the effect of education on income inequality was ambiguous. He concluded that the nature of the data could be a major factor for the contradictory and inconclusive nature of the results.

Barro (1991) used the neoclassical growth models developed by Solow (1956), Cass (1965), and Koopmans (1965), and the recent theories of economic growth as proposed by Lucas (1988), Rebelo (1990), Romer (1989), and Becker, Murphy, and Tamura (1990) as a guide to test convergence in real per capita GDP for 98 countries during the period 1960 to 1985. His results suggested that poor countries tend to catch up with rich countries if the poor countries have high per capita human capital in relation to their level of per capita GDP, but not otherwise. He observed that countries with high human capital have low fertility rates and high ratios of physical investment to GDP.

Barro and Sala-i-Martin (1992) used the neoclassical growth models developed by Ramsey (1928), Solow (1956), Cass (1965), and Koopmans (1965) to test for convergence across the 48 contiguous U.S. states using personal income since 1840 and gross state product since 1963. Their results indicated that the 48 states provided clear evidence of convergence, but the results could be reconciled quantitatively with the neoclassical model only if diminishing returns to capital set in slowly. The results for per capita GDP from a broad sample of countries were similar if a set of variables that proxy for differences in steady-state characteristics were held constant.

Mankiw et al. (1992) examined whether the Solow growth model was consistent with the international variation in the standard of living. They showed that an augmented Solow model that included accumulation of human capital provided an excellent description of the cross-country data. While testing the convergence-divergence hypothesis, they concluded that holding population growth and capital accumulation constant, countries converge at a rate the augmented Solow model would predict.

2.3 Studies Using Models of Economic Growth

The research on economic growth predominantly focuses on long-run economic progress, and the dominant sources are the neoclassical growth models developed by, to name a few, Solow (1956), Swan (1956), Ramsey (1928), Cass (1965), and Koopmans (1965). In general, the unexplained portions of growth were attributed to the area of technical progress which was treated as exogenous by the neoclassicalists. These models assumed that output can be produced using combinations of physical capital and labor in

variable proportions, and the production function was subjected to a technological factor. Thus, two exogenous processes, population growth and technological progress, determined the economy's growth rate.

In recent times with the development of endogenous growth models, the premises of neoclassical growth theory have come under serious scrutiny, thus creating the need for new techniques of measurement and analysis of the growth process. Endogenous growth models indicate that endogenizing technical progress via human capital accumulation allows an economy to grow endogenously and thus results in better measurement (Lucas 1988, 1993) and understanding of determinants of economic growth and the disparities in growth rates.

The neoclassical growth model predicts a zero growth rate of output per unit of input in the long run, since the output growth rate is entirely determined by exogenous factors like the population growth rate and the rate of technical progress. However, in the endogenous growth models, the growth rate of output per capita is a positive constant because human capital accumulation results in endogenous technical progress. The underlying fact is that neoclassical models fix the rate of growth and allow the marginal product of capital to vary, whereas the endogenous models fix the marginal product of capital but allow the rate of economic growth to be endogenous.

Lucas (1988) considered the prospects for constructing a neoclassical theory of growth and trade that was consistent with some of the main features of economic development. He studied three models to account for the disparities in growth rates across economies: a model emphasizing physical capital accumulation and technological

change, a model emphasizing human capital accumulation through schooling, and a model emphasizing specialized human capital accumulation through learning by doing. He concluded that, with the inclusion of human capital in the production function, economies that are initially poor will remain relatively poor, though their long-run rate of income growth will be as that of initially wealthier economies. If traded goods are included in the model, the long-run relationship between the two kinds of capital implies the same marginal productivity of physical capital, no matter what the level of capital that has been accumulated. If labor is mobile, it will flow in general from poor countries to wealthy ones.

Rebelo (1990) described a class of endogenous growth models that have constant returns to scale technologies. He hypothesized that this class of models rationalizes the existence of permanent cross-country differences in growth rates as being, at least partly, a result of differences in government policies. His analysis revealed that small differences in policy regimes could easily mean the difference between growth and stagnation.

Tamura (1991) developed an endogenous growth model that produced convergence in per capita income and growth rates of output. His analysis was based on the premises that agents have identical preferences and access to identical technologies of production and investment, but differing levels of human capital. He concluded that a spillover effect of human capital in the investment technology provides below-average human capital agents with a higher rate of return on investment than above-average human capital agents; thus, below-average human capital agents grow faster than above-

average human capital agents. Convergence arises because below-average human capital agents gain most from learning.

Glomm and Ravikumar (1992) studied the effect of endogenous growth on income inequality by using an overlapping generations model with heterogenous agents in which human capital investment through formal schooling was the engine of growth. They used simple functional forms for preferences (logarithmic), production technologies (linear), learning technology (Cobb-Douglas), and income distribution (lognormal) to highlight the distinction between the economies with public education and those with private education. They found that income inequality (measured by the standard deviation of the lognormally distributed incomes) declined more rapidly under public education. On the other hand, private education yielded greater per capita incomes unless the initial income inequality was sufficiently high. They also concluded that societies would choose public education if a majority of agents have incomes below average.

Lucas (1993) made a case study of the economic growth of Philippines and South Korea as a key to emphasize the effect of on-the-job human capital accumulation on growth. With this modification to the neoclassical model, an economy with a human capital stock lower than the world average would grow faster than an above average economy. His theory indicated that, relative to the world's income and human capital, a country's human capital converged to 1 which implied that relative incomes converge to 1 at the same rate. He also observed that convergence is more likely over subsets of countries or regions of countries, where factor and final goods mobility is high. He concluded that the main engine of economic growth was the accumulation of human

capital and the main source of differences in living standards among nations was differences in human capital.

Romer (1994) studied the origins of endogenous growth models and traced them back to the question of whether per capita income in different countries was converging. He observed that the most important policy questions about growth pertain to institutional arrangements for gaining access to knowledge and the production and use of new knowledge.

2.4 Studies Using Time-Series Analysis

Weatherspoon (1993), and Weatherspoon et al. (1994) tested the convergence of the G-7 countries using Theil's inequality (entropy) index on income and three other potential factors of influence on economic growth: government expenditure, investment expenditure, and industrial employment. Pairwise convergence was supported for all four variables for the time period of 1950 to 1988. It was determined that the inequality in all four variables for the G-7 countries has declined from 1950-1988. This suggests that the G-7 countries are becoming more equal in terms of the above-mentioned variables. The inequality-transformed variables were then tested for multiple cointegration using an I(2) procedure due to Johansen (1992). Multiple cointegration was supported for three out of four relationships suggesting that there exists a long-run equilibrium relationship among the inequalities in income, investment expenditure, and industrial employment.

Thus, the evidence from the inequality studies (Theil, 1989; Theil and Deepak, 1993a, 1993b, 1993c, 1994; Theil and Seale, 1994; Seale et al., 1994; Weatherspoon, 1993; Weatherspoon et al., 1994) seems to suggest that poor economies are diverging, rich economies are converging, and there is inconclusive evidence in certain cases. Neoclassical growth models (Barro, 1991; Barro and Sala-i-Martin, 1992; Mankiw et al., 1992) favor convergence and endogenous growth models (Lucas, 1988 & 1993; Romer, 1994; and Tamura, 1991) lean toward ambiguity.

The OECD countries were chosen for two main reasons: the evidence from the literature supports convergence (or divergence) for these countries and the availability of reliable data. In summary, the research by Theil and Deepak (1993a, 1993b, 1993c, 1994), Moss et al. (1993), Seale et al. (1994), and Theil and Seale (1994) determined that during the period 1950-1990 the income of the G-7, non-EU, and EU Center countries increased while the inequality declined almost uninterruptedly favoring the convergence component of Kuznets' hypothesis; the income for EU Periphery countries increased but inequality fluctuated during 1950-1970 without a clear trend and then decreased showing evidence of transition from divergence to convergence components of Kuznets' hypothesis; the North, consisting of 22 countries, also showed evidence of convergence and in the case of the countries in South, the results were inconclusive. In the process of analyzing convergence across 98 countries, Barro (1991) concluded that the evidence from 20 OECD countries was stronger because these countries had higher per capita incomes and had similar basic economic and political institutions. Further, Weatherspoon (1993) and Weatherspoon et al. (1994) found that, in the long run, the G-7

and 14 OECD countries were becoming more equal in terms of income, investment expenditure, government expenditure, and industrial employment.

The survey of the above literature on income convergence suggested that testing for convergence (or divergence) with a combination of the theories on income inequality and economic growth would prove to be an exercise that could expand the horizons of contemporary research on the subject. The evidence also suggests that though researchers have failed to reject the Kuznets' hypothesis to a large extent, they, however, failed to define, with any certainty, the determinants of convergence (or divergence) until recently. This study expanded on the above mentioned studies (Barro, 1991; Mankiw et al., 1992; Weatherspoon, 1993) and incorporated the aspects of the theory of endogenous growth to explain the process of convergence (or divergence).

Barro (1991) analyzed convergence in 98 countries during 1960-1985 by studying the relationship between growth rates in per capita income, levels of per capita income, and initial level of human capital (proxied by school enrollment ratios in 1960). He found that, holding levels of human capital constant, the growth rate in per capita income was inversely related to the level of per capita income. Further, holding the initial level od per capita income constant, Barro found that there was a positive relationship between the growth rate of income and level of human capital. Therefore, in his study, convergence was evident only in countries with high levels of initial human capital and per capita income.

This study carried Barro's research a step forward by analyzing the effects of levels of human capital, openness, investment and government expenditures on the levels

of per capita income. A multiple-variable indicator was used to estimate the level of human capital via a latent variable approach. The per capita income, estimated as a function of human capital (as a latent variable), was then analyzed for convergence with help of Theil's inequality index. This study also analyzed the convergence behavior in the determinants of income.

CHAPTER 3

DATA

The three sources of data for this dissertation were the Supplement to Mark 5 or the Penn World Tables (PWT 5.5) compiled by Summers and Heston (1993), Basic Facts and Figures compiled by UNESCO (1951-1962), and The Statistical Yearbook compiled by UNSECO (1963-1993). The data on income, population, international openness, government expenditure, and investment expenditure were extracted from the Summers and Heston data. The data on the four indicators for human capital--public expenditure on education as a percentage of income, per capita consumption of newsprint, levels of education at the secondary school and university levels--were compiled from the two UNESCO series. The data span 36 years, 1955 to 1990. Though there are 24 countries in the OECD group, the data for Iceland and Luxembourg were insufficient to include them in this study.

Due to the nature and complexity of the PWT data, their compilation procedure is discussed in this chapter. For greater details of construction of these data, please refer to Weatherspoon (1993) who discussed this subject at great length.

3.1 Penn World Tables

The PWT data efforts date back to 1978 with the formation of the International Comparison Project (ICP) (Kravis et al., 1978a). This project attempted to compile Real Gross Domestic Product Per Capita (RGDP) for more than 100 countries where RGDP is the gross domestic product per capita adjusted for differences in the purchasing power of currencies. The objective of the ICP was to approximately fill the gap in the world statistical system arising from the absence of comparative data on "real" GDP per capita. The motivation for this project came from the widely accepted fact that the exchange-rate conversions of the GDPs of different countries to a common currency such as the United States dollar did not yield a reliable basis for international comparisons.

The compilations in the ICP were based on the "nominal" values of the gross product obtained from a country's national accounts. Therefore, the comparisons based on nominal values gave systematically incorrect estimates as exchange rates deviated from the conversion factors in systematic ways. The PWT data were constructed from intertemporal and interspatial extrapolations on ICP and non-ICP data and were compiled in a manner consistent with the national income identity. Thus, the nature of compilation of the PWT data makes them very valuable for empirical research. However, to comprehend the nature of the PWT data and appreciate the benefits from using PWT data over the ICP data, one needs to understand the construction and development of the ICP data. Sections 3.1.1 to 3.1.5 discuss the ICP data briefly.

3.1.1 International Comparison Project

Phase I of the international comparison project (ICP) began with a pilot study in 1967, initiated by Kravis et al. (1975), at the University of Pennsylvania, which resulted in data collection for 10 countries for 1970 (Table 3.1). Two successive volumes, Phase II and Phase III, were published in 1978 and 1982. Phase II compiled data for an additional six countries and corrected the data from Phase I. Phase III compiled data, for 1975, for an additional 18 countries taking the count to 34 countries. Phase IV of this project, with 60 countries in 1980, was completed in two stages by the Statistical Office of the United Nations Secretariat (1985 and 1987). However, seven countries from Phase III withdrew from the study during this period. Therefore, there were 10, 16, 34, and 60 countries, in Phases I, II, III, and IV, respectively.

In the first stage of the ICP, a classification system for gross domestic product (GDP) was developed which divided each country's GDP into numerous detailed categories. GDP data were then collected for each category. Further, prices and quantities for each item within a category were also gathered.

The classification system follows the scheme proposed by the system of national accounts (SNA). This classification system was improved upon to facilitate international comparability of the data (Kravis et al., 1975). In Phases I and II, there were a total of 153 detailed categories: 110 for consumption, 38 for capital formation, and five for government. Phases II and IV have 151 detailed categories: 108 for consumption, 38 for capital formation, and five for government.

Table 3.1 - Countries Represented in the International Comparison Project

Africa	America	Asia	Europe
		Countries represented in Phase I	
Kenya	Columbia	India	France
	United States	Japan	W. Germany
			Hungary
			Italy
			United Kingdom
		Countries added in Phase II	
		Iran	Belgium
		S. Korea	Netherlands
		Malaysia	
		Philippines	
		Countries added in Phase III	
Malawi	Brazil	Pakistan	Austria
Zambia	Jamaica	Sri Lanka	Denmark
	Mexico	Syria	Ireland
	Uruguay	Thailand	Luxembourg
			Poland
			Romania
			Spain
			Yugoslavia
		Countries added in Phase IV	
Botswana	Argentina	Hong Kong	Finland
Cameroon	Bolivia	Indonesia	Greece
Ethiopia	Canada	Israel	Norway
Ivory Coast	Chile		Portugal
Madagascar	Costa Rica		
Mali	Dominican Rep.		
Morocco	Ecuador		
Nigeria	El Salvador		
Senegal	Gautemala		
Tanzania	Honduras		
Tunisia	Panama		
Zimbabwe	Paraguay		
	Peru		
	Venezuela		
		Countries deleted in Phase IV	
	Jamaica	Iran	Romania
	Mexico	Malaysia	
		Syria	
		Thailand	

Source: Theil et al. 1989, p. 2.

The three categories of data used for classification were GDP or expenditure data, price data for each item for which a price could be identified, and quantity data for the items for which prices could not be identified. The expenditure data were obtained from the U. N. national accounts data. Once the base data were collected, there were steps and alternatives to calculating purchasing power parities (PPPs) for each country.

3.1.2 Purchasing Power Parities

Purchasing power parity (PPP) is the number of currency units required to buy goods equivalent to what can be bought with a unit of currency of the base country (Kravis et al., 1982). From the several methods that can be used to calculate PPPs, the most frequently used by the ICP were the country-product-dummy (CPD) and Elteto-Koves-Szulc (EKS) methods.

These two methods are identical if all the prices for every item in each country are available. In that event, the PPPs obtained from both methods are geometric means of all the prices in the detailed category α for country c (Kravis et al., 1975). The geometric mean in country c is obtained as

$$GM_c^{\alpha} = \left(\prod_{i=1}^{m} P_{i,c}\right)^{1/m} \qquad i=1,\ldots,m \tag{3.1}$$

where $P_{i,c}$ is the price of the item i in country c and m is the number of items.

3.1.3 Country-Product-Dummy Method

The CPD is based on the assumption that the natural logarithm of the price of the item i in country c includes an item effect and a country effect; PPPs are estimated by least squares; and the relationship is stochastic. The CPD equation is

$$1/m\ (\ln(P_{i,c}))\ =\ A_i + B_c + e_{i,c} \tag{3.2}$$

where $P_{i,c}$ is the price of the item i in country c, m is the number of items, $e_{i,c}$ is normally distributed with mean zero and variance σ^2, A_i is the item effect on the price i in country c, and B_c is the country effect on the price. In most cases this method is normalized with U. S. as the base country.

3.1.4 Elteto-Koves-Szulc Method

The EKS method consists of four steps: calculate "Laspeyres" and "Paasche" type price indices; calculate "Fisher" binary price indices; fill in the Fisher matrix if needed; and finally, build an EKS matrix of transitive parities. All calculations in the EKS method are based on the prices of the "characteristic" items. A characteristic item of a country is one that is considered to be purchased frequently within that country. Each country nominates at least one such product within each detailed category. The characteristic item chosen must also be priced in at least one other country.

The price indices calculated in the first step of the EKS method are not true Laspeyres and Paasche indices and thus, they are called mini-Laspeyres and mini-Paasche price indices due to their similarity to the Laspeyres and Paasche indices in time-series

measurement. The difference is that the ratios in the EKS method are unweighted, unlike in time-series measurement. The general representation of the mini-Laspeyres index is

$$L^{\alpha}_{c,d} = \left[\prod_{i=1}^{m} \frac{P_{i,c}}{P_{i,d}} \right]^{1/m} \tag{3.3}$$

where c and d are two different countries and m is the number of characteristic items in category α. Similarly, the mini-Paasche index is obtained as

$$P^{\alpha}_{d,c} = \left[\prod_{i=1}^{m} \frac{P_{i,d}}{P_{i,c}} \right]^{1/m} \tag{3.4}$$

This method does not pick one base country, and thus, a matrix of mini-Laspeyres indices is created between countries with a diagonal of ones. The same is true for the mini-Paasche indices.

Once the mini-Laspeyres and mini-Paasche indices are computed, the mini-Fisher price indices are constructed. The latter indices are the unweighted geometric means of the former two indices

$$F^{\alpha}_{c,d} = (L^{\alpha}_{c,d} * P^{\alpha}_{c,d})^{1/2} \tag{3.5}$$

The matrix of mini-Fisher indices is not transitive, and the EKS method is applied to make them so.

The equation for the EKS method is

$$EKS^{\alpha}_{c,d} = \left[F^{\alpha^2}_{c,d} \prod_{e=1}^{n} \frac{F^{\alpha}_{c,e}}{F^{\alpha}_{d,e}} \right]^{1/n} \qquad where\ e \neq c,d. \tag{3.6}$$

This is the PP for the detailed category α between countries c and d. The last step of the EKS method is to choose one country as a base country so that it can be compared with the CPD results. A base country can be chosen by observing the values in any of the country columns of the EKS matrix. If all the prices of items are available and are characteristic items, then the EKS method is the same as equation (3.1) if $P_{i,c}$ is replaced with a price index.

Without the basic prices, the CPD method does not equal a geometric mean and neither does the EKS method. This is due to the fact that the respective price indices in these methods cannot be computed with missing prices. An illustration to demonstrate the computations of PPPs is given in Kravis et al. (1975).

3.1.5 The Geary-Khamis Method

After estimating the PPPs, the second stage of the ICP was initiated. The Geary-Khamis method provides multilateral base-invariant price and volume comparisons at the various levels of aggregation for all countries, where the volumes are expressed in "international dollars". These volumes are additive across expenditure categories, while prices are obtained by dividing expenditures in national currency by those in international dollars.

Geary suggested a system of homogeneous linear equations to calculate the international prices and PPPs simultaneously. Khamis proved that this system yielded

non-negative international prices and PPPs. The CPD or EKS method can be used to produce the detailed category PPPs for the Geary-Khamis method. These PPPs are transitive and are relative to the U.S. dollar. Detailed categories are indicated by the subscript $\alpha = 1,\ldots, A$. The volume of detailed category α in country c is

$$V_{\alpha,c} = E_{\alpha,c}/PPP_{\alpha,c} \tag{3.7}$$

where $E_{\alpha,c}$ is the per capita expenditure (in national currency) on detailed category α in country c. This volume is expressed in U.S. dollars.

However, these volumes are not additive over the detailed categories. This method introduces the international price P_α of each detailed category and the overall purchasing power parity π_c of each country c. P_α is written as

$$P_\alpha = \frac{\sum_{c=1}^{N} (E_{\alpha,c}/\pi_c)}{\sum_{c=1}^{N} V_{\alpha,c}}$$

which is equivalently written as

$$P_\alpha V_\alpha = \sum_{c=1}^{N} (E_{\alpha,c}/\pi_c) \qquad where \quad V_\alpha = \sum_{c=1}^{N} V_{\alpha,c} \tag{3.8}$$

while π_c is defined as

$$\pi_c = \frac{\sum_{\alpha=1}^{A} E_{\alpha,c}}{\sum_{\alpha=1}^{A} P_\alpha V_{\alpha,c}}$$

which is also

$$GDP_c(1/\pi_c) = \sum_{\alpha=1}^{A} P_\alpha V_{\alpha,c} \tag{3.9}$$

where GDP_c (the gross domestic product of country c in national currency) is equal to

$$GDP_c = \sum_{\alpha=1}^{A} E_{\alpha,c} \ .$$

It can be readily verified that (3.8) and (3.9) constitute a linear system of equations with (A + N - 1) unknowns in P_α and $1/\pi_c$ ($\pi_c = 1$ for c= U.S.) (Theil et al., 1989). The product $P_\alpha V_{\alpha,c}$ is interpreted as real expenditure per capita in international dollars on category α in country c, and this product is additive over all categories. Let S be any grouping of such categories, then the sum over the categories within this group S of the real expenditure gives the real gross domestic product (RGDP) per capita in international dollars on S in country c. If S consists of all detailed categories, this sum is GDP per capita in c. Further discussions of intricacies in construction can be found in Weatherspoon (1993).

3.2 Extrapolations with ICP Data

There are five publications of the extrapolations on the different phases of the ICP, the first by Kravis et al. (1978b), and the rest by Summers and Heston also known as the Mark 1 (1980), Mark 3 (1984), Mark 4 (1988), and Mark 5 (1991) (MARK 2 was not published, but used by Kravis et al. 1982). This study used data from a supplement to the MARK 5 data compiled by Summers and Heston in 1993. Therefore, only the

MARK 5 data is discussed at length. For detailed discussions of the other data sets, please see Weatherspoon (1993).

The purpose of the first paper by Kravis et al. (1978b) was to fill the gap in the world statistical system for comparative data on "real" GDP per capita for a large number of countries. The contribution of the second paper by Summers and Heston (1980) was that they extrapolated the data for the ICP and non-ICP countries forward and backward through time. The third publication by Kravis et al. (1982) had two benchmark years, 1970 and 1975, unlike the previous papers which had only 1970. The fourth publication also by Summers and Heston (1988) was basically an update of the MARK 3 data set.

The regression equation used to summarize the 1970 and 1975 cross-section relationship in Mark 3 (Summers and Heston, 1984) study was

$$\ln r_j = \alpha_1(\ln n_j) + \alpha_2(\ln n_j)^2 + \alpha_3(\ln(OP_j) + u_j \tag{4.1}$$

where

$$r_j = (\, DA_j/PPP^{DA}{}_j\,) \,/\, DA_{US} \quad \text{and} \qquad n_j = (\, DA_j/XR_j\,)/DA_{US}.$$

$PPP^{DA}{}_j$ is the purchasing power parity over domestic absorption, and XR_j is the exchange rate. They are both expressed in national currency units of the jth country per U.S. dollars. OP_j is the measure of relative openness of the jth economy defined as

$((\text{Exports}_j + \text{Imports}_j)/\text{GDP}_j\,) \,/\, (\,(\text{Exports}_{US} + \text{Imports}_{US})/\text{GDP}_{US}\,)$,

an average of the ratio for five years before the cross-section year. The α's have the same expected signs as in Kravis et al. (1978b).

In Summers and Heston (1980), $RGDP_{j,t}$ was based on constant prices while in Mark 3, international trade was incorporated into RGDP. The extrapolations in this data set were also treated differently and were computed at a greater disaggregated level. Data on consumption, gross domestic investment, government expenditure, and the net foreign balance, culled out from the U.N. constant-price series, were used to get real individual components expressed in 1975 international dollars for each of the years between 1950 and 1980.

Mark 4 (Summers and Heston, 1988) updated the Mark 3 set. The major effort behind this project was to make the data more consistent, that is, the estimates need to adhere to the national income identity which states that total product equals total income generated by the production of the product. The implementation of consistency was done via an error-in-variables model. The objective was to adjust both the benchmark and national accounts data to make them consistent. The maximum likelihood procedure used to solve this model corrected the data sources so that they were consistent. However, a weakness of this procedure was that the asymptotic properties of maximum likelihood were not applicable. Mark 4 did not incorporate the openness variable since the exchange rates were greatly volatile during the 1970s.

3.3 Mark 5 Data Set

MARK 5 covered 139 countries and RGDP per capita was obtained by extrapolating cross-section comparisons interspatially to non-benchmark countries and intertemporally to other years. This data set was based on ICP data from four

benchmark years: 1970, 1975, 1980, and 1985. Eighty-one countries participated in these benchmark studies and 47 participated in more than one study. Therefore, the need for relying on non-benchmark estimating methods was reduced. The national accounts data have also improved by using the World Bank's archive data. The methodology for obtaining RGDP per capita for a large number of countries has improved. All these factors make the MARK 5 the most accurate data published in recent times.

The four ICP benchmark studies, Phases II to V, used in this study were all compiled in different ways and have different countries participating in different years. This is why the data needed to be made intertemporal and interspatial. Since the Phase V data were not published at that time, the authors had to calculate the RGDPs on their own using raw data from the U.N. and The World Bank.

The countries that participated in the 1985 benchmark comparisons form five groups: 22 OECD countries, 11 Asian countries including Japan, 22 African countries, five European Group II countries including Finland and Austria, and a group of Caribbean countries. The Caribbean countries' comparisons were not complete at that time. The Geary-Khamis method was implemented for the OECD and Asian countries. The African countries, Hungary, Poland, and Yugoslavia all had data that allowed them to be linked to the OECD and Asian countries. The total number of countries from Phase V used in this study was 57.

A different method was used for those countries which did not participate in the 1985 benchmark study, but which had participated in a previous benchmark study. The procedure was to value their 1975 or 1980 estimates of consumption (C), investment (I),

and government (G) expenditures at 1985 international prices. The growth rates for their components from the national accounts data and their change in international prices of the components between 1975 and 1985 or 1980 and 1985 were used. The changes in international prices were estimated from the benchmark estimates and the deflator for the numeraire country, the U.S. The 1975 and 1970 data were also re-analyzed. The May 1990 national accounts data were used for these revisions. The Geary-Khamis method was then used to aggregate the data.

After the aggregation and re-estimations of the benchmark data, the non-benchmark countries RGDP per capitas were estimated. A post-allowance PPP was computed by dividing the national currency by the PPP implicit in the post adjustment index. A structural relationship was found in the benchmark countries between PPP and its post-allowance PPP. This relationship was used to estimate non-benchmark countries' missing PPPs from their post-allowance PPPs. There were 81 benchmark countries and 57 non-benchmark countries that had to be estimated. The authors performed 12 different regressions for the benchmark studies and then these were used to obtain the non-benchmark estimates. Geary-Khamis method was used to aggregate the data resulting in consistent national absorption for all countries. It was still apparent that RGDP for poor and African countries were less accurate than estimates for rich countries.

3.4 Data for Estimation

A supplement to the PWT5 data set, PWT 5.5, was compiled by Summers and Heston in 1993. This data set, in 1985 international prices, spans the years 1950-1990 for most countries. The information necessary for this study were extracted from this data set. A description of the variables tabulated in this document are listed in Table 3.2.

Data on population (POP) and GDP per capita (RGDPCH) for the 22 OECD countries during 1955-1990 were used in estimation as tabulated. Shares of real investment and real government expenditures (i_j and g_j) for country j (j=1 to 22) were used to compute per capita levels of real investment and government expenditures, I_j and G_j, respectively.

$I_j = i_j * RGDPCH_j$

$G_j = g_j * RGDPCH_j$

International openness, O_j, which represents the per capita level of exports and imports was compiled using $OPEN_j$ variable as follows

$O_j = OPEN_j * RGDPCH_j$

where

$OPEN_j = \{EXPORTS_j + IMPORTS_j\} / CGDP_j$

and $CGDP_j$ is the per capita nominal income in country j.

Both the UNESCO series, Basic Facts and Figures (1951-1961) and the Statistical Yearbook (1963-1993), income and population figures from the Summers and Heston (1993) data were used to compile information on the four indicators of human capital for

Table 3.2 - Description of Variables in PWT 5.5 File

Variable	Description
POP	Population in 000's
RGDPCH	Real GDP per capita in constant dollars (Chain Index) (expressed in international prices, base 1985.)
c	Real Consumption share of GDP [%] (1985 intl.prices)
i	Real Investment share of GDP [%] (1985 intl. prices)
g	Real Government share of GDP [%] (1985 intl. prices)
RGDPL	Real GDP per capita (Laspeyres index) (1985 intl. prices)
RGDPTT	Real GDP per capita in constant dollars adjusted for changes in terms of trade (1985 international prices for domestic absorption and current prices for exports and imports.)
Y	CGDP relative to U.S. [%] (U.S.=100, current intl. prices)
CGDP	Real GDP per capita (current intl. prices)
cc	Real Consumption share of GDP [%] (current intl. prices)
ci	Real Investment share of GDP [%] (current intl. prices)
cg	Real Government share of GDP [%] (current intl. prices)
P	Price level GDP [%] (PPP GDP/ U.S. dollar exchange rate)
PC	Price level Consumption [%] ([PPP of C]/XR)
PI	Price level Investment [%] ([PPP of I]/XR)
PG	Price level Government [%] ([PPP of G]/XR)
XR	Exchange Rate with U.S. dollar
RGDPEA	Real GDP per Equivalent Adult (1985 intl. prices)
RGDPW	Real GDP per Worker (1985 intl. prices)
OPEN	Openness (Exports + Imports) / Nominal GDP

Summers and Heston, 1993.

the 22 OECD countries during 1955-1990. Per capita public expenditure on education (PE_i) for country i (i= 1 to 22) was compiled as

$PE_i = pe_i * RGDPCH_i$

where pe_i was the public expenditure on education as a percentage of income. Per capita consumption of newsprint (CN_i) for country i, expressed in metric tons, was compiled directly as tabulated in the UNESCO series[1]. Education at the secondary school level (ES_i) and university (or equivalent) level (ET_i) in country i were compiled as

$ES_i = es_i / POP_i$

$ET_i = et_i / POP_i$

where es_i was the total number of people with secondary school education, et_i was the total number of people with university (or equivalent) education, and POP_i was the population in country i. Thus, the variables represent the shares of the population with education at the secondary and university levels, respectively.

In total, the data set used in the estimation of the research model had 36 observations per country i (i= 1 to 22)for each of the 22 OECD countries (36 x 22 = 792 total observations) for each of the eight variables: income (Y_i), per capita public expenditure on education (PE_i), per capita consumption of news print (CN_i), education at secondary school level (ES_i), education at university (or equivalent) level (ET_i), per

[1] The data for CN in 1986, for all the countries, was not available and was substituted by the average value of 1985 and 1987.

capita international openness (O_i), per capita investment expenditure (I_i), and per capita government expenditure (G_i).

CHAPTER 4

INCOME AND HUMAN CAPITAL IN THE OECD COUNTRIES

In this chapter, levels of per capita income in 22 OECD countries are estimated (as a function of human capital, international openness, investment and government expenditures) and analyzed. Several studies analyzing the relationship between growth with human capital and income convergence have used multiple regression techniques (Barro, 1991; Barro and Sala-i-Martin, 1992; Mankiw et al., 1992) and mathematical optimization techniques (Lucas, 1988, 1993). Tallman and Wang (1992) reviewed neoclassical and endogenous growth models to argue that improvements in formulating human capital measures in growth models could help establish a stronger link between human capital and growth. Weatherspoon (1993) used Theil's inequality index to measure inequality in income, industrial employment, investment expenditure, and government expenditure for the G-7 and 14 OECD countries during 1950-1985. He then used cointegration analysis to test for a long-run relationship among these inequalities.

The basic premises of the model for estimation were derived from the national income identity for an open economy and the development of endogenous growth models. The national income identity states that national income is a function of consumption,

investment and government expenditures, and volume of exports and imports. International trade is one of the key determinants of economic interaction among countries and countries gain from trading goods and services by taking advantage of the differences between their endowments and by achieving economies of scale in production. These gains from trade are reflected in the growth (or decline) of national income. Further, the national income accounts provide information essential for studying the disparities in income among rich and poor countries (Krugman and Obstfeld, 1991). Growth theorists (Barro, 1991; Mankiw et al., 1992; Lucas, 1988, 1993; Romer, 1989, 1994; Tallman and Wang, 1992) have shown that accumulation of human capital is beneficial to the economy as a whole and the individual within the economy. Therefore, income was specified as a function of human capital, international openness, government expenditure, and investment expenditure. The model is discussed further in Section 4.2 of this chapter.

The objective of this study was to analyze the nature of the influence (if any) of factors of economic growth (especially human capital) on income for the 22 OECD countries (in Chapter 1) during 1955-1990. The classical econometric treatment assumes that the observed variables, endogenous and exogenous, are measured without error. Latent variable models, on the other hand, incorporate measurement error in the observed variables into the estimation process. These errors can be correlated, and multiple indicators can measure the unobservable variable. Therefore, as the level of human capital is not directly observable, this study estimated income using a latent variable model (Bollen, 1989) with human capital as the latent variable.

The layout of this chapter is as follows: Section 4.1 introduces a general latent variable model, Section 4.2 gives the estimation procedures, section 4.3 describes the empirical research model, Section 4.4 gives the results of estimation, Section 4.5 tabulates the results from estimation of per capita income and analyzes the effects of human capital, openness, investment and government expenditures on income, and Section 4.6 concludes this chapter.

4.1 General Latent Variable Model

The full latent variable model consists of a *system of structural equations*. These equations contain random variables, structural parameters, and sometimes nonrandom variables. The three types of random variables are latent, observed, and disturbance/error variables. The nonrandom variables are explanatory variables whose values remain the same in repeated random sampling (fixed or nonstochastic variables). The links between the variables are summarized in the *structural parameters*. The structural parameters are invariant constants that provide the "causal" relation between variables. The system of structural equations has two major subsystems: the latent variable model and the measurement model.

4.1.1 Structural Equations of the Model

The first component of the structural equations is the latent variable model which encompasses the structural equations that summarize the relationships between latent variables:

$$\eta = B\eta + \Gamma\xi + \zeta \tag{4.1}$$

where η is an $m \times 1$ vector of latent endogenous random variables; ξ is an $n \times 1$ vector of latent exogenous random variables; B is the $m \times m$ coefficient matrix showing the influence of the latent endogenous variables on each other; Γ is the $m \times n$ coefficient matrix for the effects of ξ on η, and contains no zero elements. The matrix (I - B) is nonsingular. The diagonal of B is always zero. ζ is the disturbance vector that is assumed to have an expected value of zero [$E(\zeta) = 0$], homoscedastic, nonautocorrelated, and which is uncorrelated with ξ.

The second component of the structural system is the measurement model:

$$y = \Lambda_y\eta + \epsilon \tag{4.2}$$

$$x = \Lambda_x\xi + \delta \tag{4.3}$$

where y ($p \times 1$) and x ($q \times 1$) vectors are observed variables. Λ_y ($p \times m$) and Λ_x ($q \times n$) are the coefficient matrices that show the relation of y to η and x to ξ, respectively. ϵ ($p \times 1$) and δ ($q \times 1$) are the errors of measurement for y and x, respectively. The errors of measurement are assumed to be uncorrelated with ξ and ζ and with each other. The expected value of ϵ and δ are zero. To simplify matters η, ξ, y, and x are written as deviations from their means. Further, ξ cannot influence any y directly; if the x and y vectors contain measurement errors, these errors cannot influence one another directly.

4.1.2 Implied Covariance Matrix

Covariance is a central concept for the above models: the covariance algebra helps in deriving properties of the latent and measurement models; and determine factors that influence sample covariances which in turn can affect parameter estimates. Two covariance matrices are part of the latent variable model: Φ (n $\times$ n), a symmetric matrix, is the covariance matrix of the latent exogenous variables(ξs); Ψ (m $\times$ m) is the covariance matrix of the errors in the latent variable model. Thus, the covariance matrix for η is a function of B, Γ, Φ, and Ψ. For the measurement model, Θ_δ (q $\times$ q) and Θ_ϵ (p $\times$ p) are the covariance matrices of the errors of measurement δ and ϵ, respectively. Specifically, $\Phi = E(\xi\xi')$, $\Psi = E(\zeta\zeta')$, $\Theta_\delta = E(\delta\delta')$, and $\Theta_\epsilon = E(\epsilon\epsilon')$.

The sample covariance matrix is crucial to the estimates of structural equation models since factors that affect this matrix have the potential to affect the parameter estimates. The n $\times$ (p + q) sample covariance matrix is computed as

$$S = \frac{zz'}{T} \tag{4.4}$$

where z is [y x]. The population covariance matrix is denoted by Σ. Σ_{yy} is the covariance matrix of y, Σ_{xx} is the covariance matrix of x, Σ_{yx} and Σ_{xy} are the covariance matrices of y with x and x with y, respectively.

Let θ denote the vector of unknown parameters. Then, Σ_{yy} (θ) is

$$\Sigma_{yy}(\theta) = E(yy') = \Lambda_y\, E(\eta\eta')\, \Lambda_y' + \Theta_\epsilon \tag{4.5}$$

Substituting the reduced form of equation (4.1)

$$\eta = (I-B)^{-1}(\Lambda\xi + \zeta)$$

in E($\eta\eta$') and simplifying we get

$$\Sigma_{yy}(\theta) = \Lambda_y (I-B)^{-1} (\Gamma\Phi\Gamma' + \Psi) \left[(I-B)^{-1}\right]' \Lambda_y + \Theta_\varepsilon \tag{4.6}$$

which shows that the covariance of y is a complex function of six of the eight model parameter matrices or vectors. Similarly,

$$\Sigma_{yx}(\theta) = E(yx') = \Lambda_y (I-B)^{-1} \Gamma\Phi\Lambda_x' \tag{4.7}$$

and

$$\Sigma_{xy}(\theta) = \Sigma_{yx}(\theta)' = \Lambda_x\Phi\Gamma' \left[(I-B)^{-1}\right]' \Lambda_y' \tag{4.8}$$

Further,

$$\Sigma_{xx}(\theta) = E(xx') = \Lambda_x E(\xi\xi') \Lambda_x' + \Theta_\delta \tag{4.9}$$

Substituting for E($\xi\xi'$) we have

$$\Sigma_{xx}(\theta) = \Lambda_x\Phi\Lambda_x' + \Theta_\delta \tag{4.10}$$

Therefore, the covariance matrix Σ (θ) for the observed y and x variables as a function of the model parameters is

$$\Sigma(\theta) = \begin{bmatrix} \Sigma_{yy}(\theta) & \Sigma_{yx}(\theta) \\ \Sigma_{xy}(\theta) & \Sigma_{xx}(\theta) \end{bmatrix} \tag{4.11}$$

which can also be written as

$$\begin{bmatrix} \Lambda_y(I-B)^{-1}(\Gamma\Phi\Gamma' + \Psi[(I-B)^{-1}]'\Lambda_y' + \Theta_\varepsilon & \Lambda_y(I-B)^{-1}\Gamma\Phi\Lambda_x' \\ \Lambda_x\Phi\Gamma'[(I-B)^{-1}]'\Lambda_y' & \Lambda_x\Phi\Lambda_x' + \Theta_\delta \end{bmatrix} \tag{4.12}$$

4.1.3 Identification

Investigations of identification (Bollen, 1989) begin with one or more equations relating known and unknown parameters. Known parameters are those that are known to be identified such as variances and covariances for which consistent sample estimators are readily available. The unknown parameters are those whose identification status is not known and the researcher must establish whether unique values exist for these. The unknown parameters are from the structural equation model. Identification is demonstrated by showing that the unknown parameters are functions only of the identified parameters and that these functions lead to unique solutions. If this can be done, the unknown parameters are identified; otherwise one or more parameters are unidentified. Therefore, the objective is to solve for the unknown parameters in terms of the identifiable parameters. The parameters in θ are globally identified if no vectors θ_1 and θ_2 exist such that $\Sigma(\theta_1) = \Sigma(\theta_2)$ unless $\theta_1 = \theta_2$.

t-Rule

Let p+q be the number of observed variables, and t be the number of free and unconstrained elements in θ. The t-rule for identification (Bollen, 1989) is that the number of nonredundant elements in the covariance matrix of the observed variables must

be greater than or equal to the number of unknown parameters in θ. In other words, the necessary but not sufficient condition of identification is:

$$t < \frac{1}{2}(p + q)(p + q + 1) \tag{4.13}$$

The nonredundant elements of $\Sigma = \Sigma(\theta)$ imply $(p + q)(p + q + 1)/2$ equations. If the number of unknowns in θ exceeds the number of equations, identification is not possible.

Two-Step Rule

Under this rule (Bollen, 1989), the first step is to treat the model as a confirmatory factor analysis. This implies that the original y and x are treated as x variables, and the original η and ξ are treated as ξ variables. The only relationships between latent variables that are of concern are their variances and covariances (Φ). In short, B, Γ, and Ψ elements of equation (4.1) are ignored. This model is identified if a unique solution exists for the structural parameters Λ_x, Φ, and Θ_δ such that no vectors γ_1 and γ_2 exist that make $\Sigma(\theta_1) = \Sigma(\theta_2)$ unless $\theta_1 = \theta_2$. If the model is identified at this juncture then we move to the next step.

The second step examines the latent variable equation of the original model given by (4.1) and is treated as a structural equations model with observable variables having no measurement error. Next it is determined whether B, Γ, and Ψ are identified ignoring the measurement parameters considered in the first step (Λ_x, Φ, and Θ_δ). This is achieved by verifying the identification of equation (4.1) using the order and rank conditions prescribed for systems of equations (Bollen, 1989). The order condition is

a necessary condition which requires that the number of variables excluded from the equation to be identified are at least p-1. The rank condition is necessary and sufficient for identification and requires that the ith equation, of a system of equations, is identified if the rank of C_i is equal to p-1, where $c = [(I-B) \mid -\Gamma]$.

If the first step shows that the measurement parameters are identified and the second step shows that the latent variable model parameters are also identified, then this is sufficient to identify the model. This is so since the first step establishes that all parameters in the measurement model are identified, including the covariance matrix of the latent variables. The second step establishes whether B, Γ, Φ, and Ψ are functions of the identified covariance matrix of the latent variables. Since this is a sufficient condition for identification, a model could fail to meet it and still be identified. However, this rule exemplifies the possibility that constraints on the latent variable relations can assist the identification of measurement parameters such that even if a model failed the two-step rule, it could still be possible to find unique solutions for the unknown parameters.

MIMIC Rule

The models referred to as MIMIC (Bollen, 1989) contain observed variables that are Multiple Indicators and MultIple Causes of a single latent variable. However, the MIMIC rule applies only to models in a certain form (as below) making its applicability narrow in range. The equations in this model are:

$$\eta_1 = \Gamma x + \zeta_1$$

$$y = \Lambda_y \eta_1 + \epsilon \tag{4.14}$$

$$x = \xi$$

where x is a perfect measure of ξ and only one latent variable, η_1, is present. Then η_1 is directly affected by one or more x variables, and it is indicated by one or more y variables. Identification of the MIMIC models that conform to (4.14) follows if p (the number of ys) is two or greater and q (the number of xs) is one or more, provided η_1 is assigned a scale. Therefore, the MIMIC rule for the model in (4.14) above with $p \geq 2$ and $q \geq 1$ is a sufficient condition for identification but not a necessary one.

4.2 Estimation

The hypothesis for the generalized latent variable model is $\Sigma = \Sigma(\theta)$. Given the sample covariance matrix of the observed variables, S, θ has to be chosen such that $\Sigma(\theta)$ is close to S. Theoretically, this means that we need to minimize $\Sigma(\theta)$ to get consistent estimators of θ. Three such minimizing fitting functions are: the maximum likelihood (ML) function; the unweighted least squares (ULS) function; and the generalized least squares (GLS) function

$$F_{ML} = \log|\Sigma(\theta)| + tr\{ S\Sigma^{-1}(\theta) \} - \log|S| - (p+q)$$

$$F_{OLS} = (1/2)\ tr\ \{[I - \Sigma(\theta)S^{-1}]^2\} \tag{4.15}$$

$$F_{ULS} = (1/2)\ tr\ \{[S - \Sigma(\theta)]^2\}.$$

Each of these functions is minimized with respect to θ. Further, the estimated values of the four explanatory variables are obtained by minimizing the weighted squared errors as proposed by Bartlett (1938):

$$\hat{\xi} = (\hat{\Lambda}_x'\hat{\Theta}_\delta\hat{\Lambda}_x)^{-1}\hat{\Lambda}_x'\hat{\Theta}_\delta^{-1}x\ . \tag{4.16}$$

The estimated or predicted per capita income is computed as:

$$\hat{y} = \hat{\Gamma}\hat{\xi}\ . \tag{4.17}$$

4.3 Empirical Model

The research model in question had one endogenous variable (per capita income (Y)), one exogenous latent variable (human capital (H)), and three exogenous variables (investment expenditure (I), government expenditure (G), and international openness (O)). Income was the real gross domestic product per capita, international openness was measured as the real per capita level of exports and imports, and government and investment expenditures were measured at real per capita levels (Chapter 3, Section 3.4). Income, international openness, investment and government expenditures were assumed to be observed without error for the purposes of estimation.

The indicators for human capital were levels of per capita public expenditure on education (PE), per capita consumption of newsprint (CN), shares of population with high school education (ES), and shares of population with university or equivalent education (ET). In a review of growth models, Tallman and Wang (1992) concluded that there were potential gains from greater emphasis on higher education, which improved learning efficiency on the job and yielded significant positive external effects. This improvement in on-the-job learning was also important for promoting perpetual economic growth, adding significantly to individual human capital stock as well as to the stock of society's knowledge that may improve the quality of life (Lucas, 1993). Therefore, since PE gave an indication of the level of investment in human capital, CN indicated a level of reading, and ES and ET denoted the shares of educated population, they were feasible choices for indicators of human capital accumulation. Further, the availability of data was yet another reason for the choice of indicators.

Therefore, there were 36 observations for each of the eight variables (Y, PE, CN, ES, ET, O, I, and G) and for each of the 22 OECD countries. Since the intention was to study the convergence behavior of these countries as a group, the data were pooled making the total number of observations in each vector to be 792. Therefore, using equations (4.1), the latent variable model for estimation was

$$y = \begin{bmatrix}\gamma_1 & \gamma_2 & \gamma_3 & \gamma_4\end{bmatrix} \begin{bmatrix} H \\ O \\ I \\ G \end{bmatrix} + \zeta \tag{4.18}$$

where income was assumed to be observed without error (η=y). The measurement model for estimation, similar to equation (4.3), was

$$\begin{bmatrix} PE \\ CN \\ ES \\ ET \\ O \\ I \\ G \end{bmatrix} = \begin{bmatrix} \lambda_1 & 0 & 0 & 0 \\ \lambda_2 & 0 & 0 & 0 \\ \lambda_3 & 0 & 0 & 0 \\ \lambda_4 & 0 & 0 & 0 \\ 0 & \lambda_5 & 0 & 0 \\ 0 & 0 & \lambda_6 & 0 \\ 0 & 0 & 0 & \lambda_7 \end{bmatrix} \begin{bmatrix} H \\ O \\ I \\ G \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \\ \delta_7 \end{bmatrix} \tag{4.19}$$

where the matrix on the left-hand side consisting of PE, CN, ES, ET, O, I, G vectors corresponded to x. Λ_x was the first matrix on the right side with factor loadings wherein which λ_5, λ_6, and λ_7 were normalized to a value of one for purposes of estimation. ξ corresponded with the matrix of exogenous latent variables wherein which ξ_1 was H and ξ_2, ξ_3, and ξ_4 were assumed to be directly observable as O, I, and G, respectively. Therefore, $\delta_5 = \delta_6 = \delta_7 = 0$ for estimation. ζ was the vector of errors in η(=y).

From equations (4.6) to (4.8) and equation (4.10), we could derive the implied covariance matrix for the observed y and x variables as a function of the model parameters:

$$\Sigma(\theta) = \begin{bmatrix} \Gamma\Phi\Gamma' + \Psi & \Gamma\Phi\Lambda_x' \\ \Lambda_x\Phi\Gamma' & \Lambda_x\Phi\Lambda_x' + \Theta_\delta \end{bmatrix} \tag{4.20}$$

where Φ was the variance-covariance matrix of ξ, Ψ is the variance in η, and Θ_δ is the variance-covariance matrix of x. For the purposes of estimation, the data were treated as deviations from their means. In this model, the variance parameter of H, ϕ_{11}, was normalized to one to facilitate estimation. This implied that H $\sim$ N(0,1) which eased the statistical inference of the human capital variable. The variance parameters of O, I, and G were treated as fixed as in regular regression analysis. Additionally,

$$E(\xi\xi') = \Phi = \begin{bmatrix} 1 & \phi_{12} & \phi_{13} & \phi_{14} \\ \phi_{21} & \phi_{22} & \phi_{23} & \phi_{24} \\ \phi_{31} & \phi_{32} & \phi_{33} & \phi_{34} \\ \phi_{41} & \phi_{42} & \phi_{43} & \phi_{44} \end{bmatrix}$$

where

$$\Phi_2 = \begin{bmatrix} \phi_{22} & \phi_{23} & \phi_{24} \\ \phi_{32} & \phi_{33} & \phi_{34} \\ \phi_{42} & \phi_{43} & \phi_{44} \end{bmatrix}$$

was the matrix of variance-covariance between the observed O, I, and G. Therefore Φ_2 = S_2 from the sample variance matrix (Section 4.2). Further, the restriction that $\phi_{12} = \phi_{13} = \phi_{14} = 0$ was imposed on the Φ matrix for the purposes of estimation.[2] Thus, the Φ matrix looked like

[2]The model was estimated with and without the restriction that $\phi_{12} = \phi_{13} = \phi_{14} = 0$. The likelihood ratio test failed to reject the restriction at $\alpha=0.05$ level of significance.

$$\Phi = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \phi_{22} & \phi_{23} & \phi_{24} \\ 0 & \phi_{32} & \phi_{33} & \phi_{34} \\ 0 & \phi_{42} & \phi_{43} & \phi_{44} \end{bmatrix} \tag{4.21}$$

From equations (4.15) to (4.17) above, the empirical system of equations consisted of eight coefficients γ_i (i=1 to 4), and λ_j (j= 1 to 4)) and five variances (E($\zeta\zeta'$), and E($\delta_j\delta_j'$) (j=1 to 4) that were to be estimated. Therefore, the number of unrestricted unknowns in the θ vector of the empirical model were 13 and the t-rule value computed using equation (4.13) was 36. The empirical model, described by equations 4.15 and 4.16, was in the MIMIC form with p=1 and q=7

$$\begin{aligned} y &= \Gamma\xi + \zeta \\ y &= \eta \\ x &= \Lambda_x\xi + \delta \end{aligned} \tag{4.22}$$

Therefore the necessary and sufficient conditions for identification were met for this model.

4.4 Parameter Estimates of the Latent Variable Model

The maximum likelihood function F_{ML} as given in the previous section was used to estimate the parameters of this model. Table 4.1 gives the estimated parameters for the latent variable model (from equation 4.18) and their asymptotic standard errors of estimation. These results clearly indicate that human capital (as measured by a latent

variable), international openness, investment and government expenditures had positive and statistically significant effects on income for the 22 OECD countries.

These results complied with the theoretical underpinnings from basic macroeconomic and growth theories which indicate that growth in income was positively correlated with accumulation of capital and growth in international trade. The greatest positive effect on income was imposed by the level of human capital implying that human capital was a key determinant of income in the 22 OECD countries. This result tallied with the results put forth by Barro (1991), Mankiw et al. (1992), Tallman and Wang (1992), and Lucas (1988, 1993). The positive effect of international openness was as predicted by Romer (1990) who proposed that growth in international trade yielded positive dividends for economic growth. Mankiw et al. (1992) found that, in an augmented Solow model, a higher savings rate led to higher income and higher level of human capital. Barro (1991) found that growth in income was positively related to investment expenditures. Thus, the positive effects of investment and government expenditures were not surprising. Further, the elasticities in average income (Column 5) with respect to average levels of human capital, openness, investment and government expenditures are all positive. This also lends support to the above analysis that income is positively influenced by all the four factors and especially human capital followed by investment expenditure, government expenditure, and openness in that order.

Table 4.1 - Parameter Estimates of the Latent Variable Model
for 22 OECD Countries, 1955-1990.

Variables	Parameters	Estimates	Standard Errors	Elasticities
1	2	3	4	5
H	γ_1	11.79	0.75	0.65
O	γ_2	0.08	0.01	0.03
I	γ_3	1.58	0.04	0.46
G	γ_4	1.46	0.10	0.43
$E(\eta\eta')$	ψ	56.04	0.26	

Table 4.2 gives the estimated parameters for the measurement model (from equation 4.19) and their standard errors of estimation. The factor loadings were all positive and statistically different from zero (α=.05). This result was as expected since the indicators contributed to the accumulation of human capital (Barro, 1991; Mankiw et al., 1991; Tallman and Wang, 1992; and Lucas, 1988, 1993). Increased public expenditure on education positively influences human capital accumulation since this investment results in improvement of level of schooling, improvement in skills, and level of technology; increased consumption of newsprint denotes an increasing level of reading which in turn could indicate increases in the level of educated population; increasing shares of educated population at the secondary school and university levels indicates growth in an educated and skilled population. An increase in all four variables does indicate a better level of living standard.

Table 4.2 - Parameter Estimates of the Measurement Model for 22 OECD Countries, 1955-1990.

Variables	Parameters	Estimates	Standard Errors
1	2	3	4
PE	λ_1	2.65	0.08
CN	λ_2	1.04	0.04
ES	λ_3	1.43	0.08
ET	λ_4	0.97	0.03
$E(\delta_1\delta_1')$	θ_{11}	1.51	0.06
$E(\delta_2\delta_2')$	θ_{22}	0.54	0.02
$E(\delta_3\delta_3')$	θ_{33}	3.55	0.05
$E(\delta_4\delta_4')$	θ_{44}	0.28	0.02

4.5 Income and Human Capital in OECD Countries

Using Bartlett's method (equation 4.16) and the estimated parameters (Table 4.2), we can compute the per capita value for human capital, $\hat{H}$:

$$\hat{H} = \left(\begin{bmatrix} 2.7 \\ 1.0 \\ 1.4 \\ 1 \end{bmatrix}' \begin{bmatrix} 1.5 & & & \\ 0 & 0.5 & & \\ 0 & 0 & 3.6 & \\ 0 & 0 & 0 & 0.3 \end{bmatrix}^{-1} \begin{bmatrix} 2.7 \\ 1.0 \\ 1.4 \\ 1 \end{bmatrix} \right)^{-1} \begin{bmatrix} 2.7 \\ 1.0 \\ 1.4 \\ 1 \end{bmatrix}' \begin{bmatrix} 1.5 & & & \\ 0 & 0.5 & & \\ 0 & 0 & 3.6 & \\ 0 & 0 & 0 & 0.3 \end{bmatrix}^{-1} \begin{bmatrix} PE \\ CN \\ ES \\ ET \end{bmatrix} \tag{4.23}$$

Using equation (4.17) and the parameters of estimation from Table 4.1, per capita incomes of the 22 OECD countries are computed:

$$\hat{Y} = 11.79\ \hat{H} + 0.08\ O + 1.58\ I + 1.46\ G \tag{4.24}$$

These computations yield 792 values for human capital and per capita income for the 22 countries. Therefore, the estimation of the model yielded 36 values for each variable for each country. The values of estimated per capita income and human capital for each

country were weighted by their respective populations to yield an average per capita income and average per capita level of human capital for the 22 OECD countries as a group,

$$\hat{Y}_{OECD} = \sum_{i=1}^{22} \frac{n_i \hat{Y}_i}{N}$$

$$\hat{H}_{OECD} = \sum_{j=1}^{22} \frac{n_j \hat{H}_j}{N} ,$$

where $\hat{Y}_{OECD}$ was the per capita income of the group of 22 OECD countries, n_i (i=1 to 22) was the population of country i, $\hat{Y}_i$ (i= 1 to 22) was the per capita income of country i, $\hat{H}_{OECD}$ was the per capita level of human capital for the 22 OECD countries as a group, $\hat{H}_j$ (j=1 to 22) was the per capita level of human capital of country j, and N was the total population in the 22 countries. Similarly, average per capita levels of observed income (Y_{OECD}), openness (O_{OECD}), investment (I_{OECD}) and government (G_{OECD}) expenditures were computed for the group of 22 countries.

Table 4.3 tabulates estimated levels of human capital for the 22 OECD countries individually. For the purposes of estimation, this variable was specified to be distributed as N(0,1) to ease interpretation of results. However, while reporting the results for this variable, it was rescaled to bring it to a form comparable with that of the other variables in the model. Therefore, it has to be noted that when the values in Table 4.3 are expressed as deviations from their mean, they are still distributed as N(0,1). Table 4.4 summarizes the computations of average levels of per capita human capital, openness, investment and government expenditures for the 22 OECD countries. Column 2 of this table gives the values of average level of human capital. Therefore, the value of human

Table 4.3 Estimated Levels of Human Capital ($\hat{H}_i$, i=1 to 22) in the 22 OECD Countries, 1955-1990

Year	USA	Canada	Japan	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland
1	2	3	4	5	6	7	8	9	10	11	12
1955	450.18	373.93	335.50	350.76	333.01	368.62	376.09	339.33	363.01	304.13	332.65
1956	450.04	378.99	341.50	348.17	341.72	376.54	400.37	362.12	366.43	304.87	331.72
1957	459.95	402.90	344.42	343.18	354.48	379.60	408.97	356.55	369.38	306.26	331.27
1958	455.57	417.21	348.60	345.01	396.00	380.44	398.57	357.38	373.51	306.70	331.04
1959	470.54	432.82	352.79	362.30	406.66	387.97	411.26	358.91	381.03	309.38	333.44
1960	537.94	454.01	352.96	366.80	414.59	393.88	428.20	367.16	382.18	310.34	339.02
1961	491.22	467.99	362.01	366.12	431.15	412.96	448.71	396.54	395.88	311.16	343.84
1962	522.35	513.72	370.20	377.72	437.30	470.06	459.36	399.26	398.99	311.29	337.93
1963	544.43	509.49	378.75	385.14	415.85	473.04	468.49	395.62	403.32	314.98	352.12
1964	554.28	525.79	390.27	396.65	473.62	499.85	473.26	420.87	415.60	324.14	364.58
1965	576.34	573.77	395.25	406.40	429.11	529.92	479.00	431.08	430.32	321.20	371.79
1966	584.25	625.58	402.99	426.43	450.93	556.03	488.89	440.45	434.88	322.19	370.34
1967	551.46	578.06	382.49	409.69	423.12	496.46	465.22	405.97	403.21	318.36	361.21
1968	569.28	581.66	388.50	416.64	436.17	512.54	459.64	435.61	406.50	321.38	368.51
1969	598.91	608.68	397.84	425.03	456.79	530.09	479.01	448.39	417.86	327.02	378.91
1970	606.59	624.61	410.59	428.66	428.48	550.00	493.68	421.61	438.75	323.35	384.86
1971	624.13	636.52	419.49	437.67	432.18	577.22	493.20	425.25	459.12	323.56	385.54
1972	628.82	632.31	427.99	452.08	438.21	567.77	498.46	432.78	445.75	324.07	393.21
1973	654.12	654.18	440.13	462.83	480.79	571.16	518.54	506.64	455.91	328.17	406.46
1974	640.86	647.12	458.16	475.44	519.14	589.24	520.06	485.71	469.24	332.11	410.72
1975	609.82	662.52	472.41	487.67	523.56	594.19	534.03	515.66	493.19	333.82	435.72
1976	613.42	676.93	471.93	497.17	536.38	631.60	549.25	534.00	465.41	335.45	428.17
1977	648.37	694.28	481.83	498.94	550.21	572.90	544.50	537.35	491.30	336.18	440.59
1978	675.54	712.86	499.88	505.40	536.59	583.06	528.81	521.76	497.44	342.62	452.09
1979	666.53	706.72	512.95	511.74	546.60	566.09	517.28	449.16	502.43	343.52	469.16
1980	693.18	707.88	519.73	518.18	551.50	586.94	530.76	517.07	507.54	347.97	473.74
1981	693.78	726.47	534.51	531.20	555.15	584.92	535.52	542.92	504.86	347.81	494.22
1982	680.37	721.36	527.83	528.42	554.31	599.40	546.92	556.66	497.68	348.35	487.97
1983	680.30	722.33	527.81	537.65	552.00	603.00	543.49	564.34	498.07	348.02	468.34
1984	696.71	714.56	519.28	537.54	550.17	601.11	540.23	570.93	508.65	353.10	470.95
1985	713.03	720.79	525.50	543.20	550.83	600.72	559.90	561.15	507.49	362.26	476.93
1986	727.63	751.56	525.42	554.71	534.21	674.40	567.92	558.69	507.55	357.97	485.91
1987	739.10	756.00	529.36	555.06	528.16	692.75	578.20	559.12	510.44	357.73	487.79
1988	647.14	766.91	538.55	551.88	526.22	683.02	589.89	563.87	509.15	362.25	484.68
1989	661.49	768.33	543.57	556.02	551.44	678.68	608.96	572.87	510.12	369.55	488.01
1990	710.95	780.63	557.59	561.32	556.17	679.75	627.09	583.62	518.80	370.19	500.09

Table 4.3 (Contd)

Year	Italy	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	Turkey	UK	Australia	New Zealand
13	14	15	16	17	18	19	20	21	22	23	24
1955	331.69	387.65	369.76	302.72	304.64	356.34	379.20	305.88	366.63	377.34	384.82
1956	332.99	358.23	375.19	303.03	304.25	357.78	383.72	305.73	367.25	375.56	383.52
1957	338.74	403.86	385.55	303.43	305.68	361.66	388.59	307.68	386.70	375.39	389.24
1958	340.30	400.95	396.23	303.47	306.10	375.89	393.28	309.11	386.51	356.72	390.79
1959	346.20	411.51	408.68	307.95	310.10	382.47	400.10	308.38	394.62	397.66	392.38
1960	362.77	430.81	412.09	310.79	312.65	385.01	418.17	307.88	398.33	401.59	408.11
1961	394.38	443.53	419.48	310.45	309.40	454.59	427.01	312.21	428.33	407.55	412.65
1962	412.17	457.44	435.86	310.24	312.28	469.33	502.07	312.63	441.10	410.54	416.94
1963	420.84	469.24	459.55	310.32	315.20	515.63	499.15	314.19	448.74	416.22	420.43
1964	424.72	497.04	469.63	309.02	326.20	532.84	489.88	314.24	459.24	430.10	431.38
1965	435.90	507.57	477.49	310.06	322.89	550.21	510.01	318.24	472.68	439.84	443.82
1966	402.44	482.81	498.20	310.47	324.68	573.75	473.64	321.32	486.48	448.65	455.63
1967	422.03	499.82	465.19	308.62	327.69	609.66	476.95	320.98	456.49	437.98	435.13
1968	418.82	514.62	472.63	310.08	331.45	589.34	481.09	321.37	441.23	441.38	433.72
1969	412.48	536.25	485.50	310.52	343.25	612.96	489.60	320.43	463.59	453.87	445.53
1970	418.96	566.04	475.48	344.71	349.06	607.67	504.84	318.42	465.84	467.55	467.46
1971	433.78	577.41	498.15	320.11	350.46	611.03	516.44	329.93	479.56	486.13	491.89
1972	447.85	580.25	537.61	323.25	362.35	616.59	525.98	343.37	510.94	503.22	493.82
1973	465.31	595.38	547.16	330.08	342.92	619.65	547.24	343.63	518.19	514.77	503.62
1974	466.93	616.54	547.84	337.18	342.41	621.22	556.23	347.47	508.71	572.59	517.70
1975	452.12	632.23	560.07	350.53	350.36	624.59	549.00	351.19	512.18	579.36	511.79
1976	465.95	638.83	602.11	361.16	354.27	639.36	550.67	354.51	515.58	576.52	498.16
1977	469.70	641.12	606.20	358.85	351.87	659.77	557.14	357.76	507.12	533.92	497.65
1978	457.17	651.91	639.41	368.42	365.75	693.12	552.77	335.58	507.69	461.35	496.76
1979	485.58	657.63	646.36	365.01	367.76	704.35	555.29	334.37	510.46	573.66	488.09
1980	495.49	631.94	627.18	378.35	368.12	716.36	570.91	323.64	513.97	575.46	507.46
1981	494.27	625.45	614.41	384.84	369.16	716.65	566.32	325.69	504.40	580.05	513.52
1982	493.64	610.86	618.17	388.61	372.25	711.18	567.00	325.73	504.66	579.13	504.23
1983	482.30	585.12	631.95	375.45	375.32	689.90	573.76	331.59	505.21	585.15	502.49
1984	499.41	584.82	637.16	378.64	386.77	691.67	572.21	323.98	501.98	626.88	503.87
1985	500.03	591.31	643.34	381.79	388.56	681.16	569.92	321.14	500.43	629.52	486.85
1986	505.76	599.99	674.67	381.72	389.01	683.17	583.93	320.59	512.98	595.49	523.13
1987	512.33	618.00	694.03	389.90	395.06	683.35	583.05	316.55	519.16	567.55	533.16
1988	521.26	602.00	700.72	403.04	427.52	654.16	596.18	317.65	525.44	565.52	541.48
1989	527.79	594.71	725.45	410.67	442.02	694.70	598.70	317.49	525.93	581.28	579.73
1990	446.14	600.33	738.22	420.10	447.71	715.51	615.29	337.99	536.10	585.93	607.98

Table 4.4 - Average Per Capita Levels of Human Capital ($\hat{H}_{OECD}$), International Openness (O_{OECD}), Investment Expenditure (I_{OECD}), and Government Expenditure (G_{OECD}) in the 22 OECD Countries, 1955-1990

Year	Human Capital	International Openness	Investment Expenditure	Government Expenditure
	$\hat{H}_{OECD}$	O_{OECD}	I_{OECD}	G_{OECD}
1	2	3	4	5
1955	372.83	1283.14	1430.91	804.33
1956	375.89	1365.37	1457.26	808.44
1957	383.16	1422.75	1450.56	823.91
1958	384.16	1315.70	1404.01	828.75
1959	393.24	1393.18	1541.13	840.97
1960	416.43	1542.55	1639.43	852.70
1961	415.14	1568.23	1720.29	889.76
1962	431.45	1602.20	1815.93	927.39
1963	441.45	1675.17	1898.90	948.58
1964	453.25	1790.54	2066.63	964.09
1965	466.20	1865.29	2183.51	986.99
1966	471.55	1959.88	2287.96	1041.05
1967	450.93	2002.95	2316.70	1098.33
1968	458.80	2179.37	2476.89	1122.68
1969	474.78	2364.32	2646.05	1132.43
1970	481.22	2542.15	2703.16	1150.82
1971	493.73	2608.37	2757.89	1166.60
1972	501.24	2717.41	2882.64	1175.46
1973	519.74	3088.94	3149.99	1194.64
1974	519.92	3715.18	3017.30	1220.03
1975	518.27	3341.05	2633.05	1248.78
1976	521.36	3638.81	2870.10	1271.79
1977	534.82	3722.07	2973.74	1285.45
1978	543.37	3717.13	3074.45	1318.60
1979	542.60	4094.06	3176.32	1342.82
1980	557.36	4368.00	3060.20	1360.88
1981	561.50	4435.24	3016.31	1375.90
1982	556.70	4269.67	2789.60	1392.52
1983	556.29	4254.21	2844.59	1419.41
1984	562.79	4665.34	3187.09	1450.12
1985	568.16	4733.06	3254.57	1489.07
1986	574.88	4402.15	3329.83	1530.81
1987	580.36	4519.56	3487.03	1560.68
1988	557.26	4795.09	3733.70	1583.16
1989	565.66	5158.82	3949.07	1585.50
1990	581.93	5276.98	4003.32	1610.41

capital was increasing over time implying that the level of human capital has been increasing over time for the 22 OECD countries. From columns 3 to 5 of this table, it can be seen that average per capita levels of openness, investment and government expenditures, respectively, were also increasing over time though at different rates. Figures 4.1 and 4.2 depict these patterns clearly. These results indicate that the per capita income could be expected to increase over time as evidence from literature had suggested (Barro, 1991; Mankiw et al., 1992).

Further, comparing the estimated levels of human capital in the individual countries to the average level (from Table 4.3, Table 4.4, and Figure 4.3) revealed that six countries (USA, Canada, Denmark, Netherlands, Norway, and Sweden) had above average levels, nine countries (Japan, Austria, West Germany, Greece, Ireland, Italy, Portugal, Spain, and Turkey) had below-average levels, and seven countries (Belgium, Finland, France, Switzerland, UKD, Australia, and New Zealand) tracked the average closely.

Tables 4.5 and 4.6 give the values of observed and estimated income for the 22 countries separately. Columns 2 and 3 of Table 4.7 give the average levels of per capita observed and estimated incomes (Y_{OECD} and $\hat{Y}_{OECD}$) for the 22 countries. At a glance, this table reveals that (i) income (observed and estimated) was increasing over time, and (ii) the estimated income values fit the observed income values quite closely. Further, from this table and Figure 4.4, the estimated income is initially lower than the observed income. Towards the end of the period the estimated income is lower than the observed

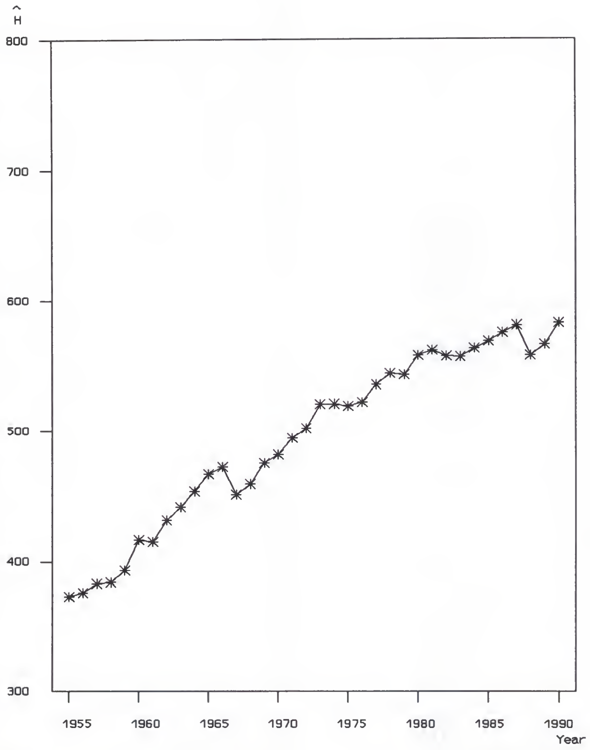


Figure 4.1 Average Level of Human Capital ($\hat{H}_{OECD}$) in the 22 OECD Countries, 1955-1990

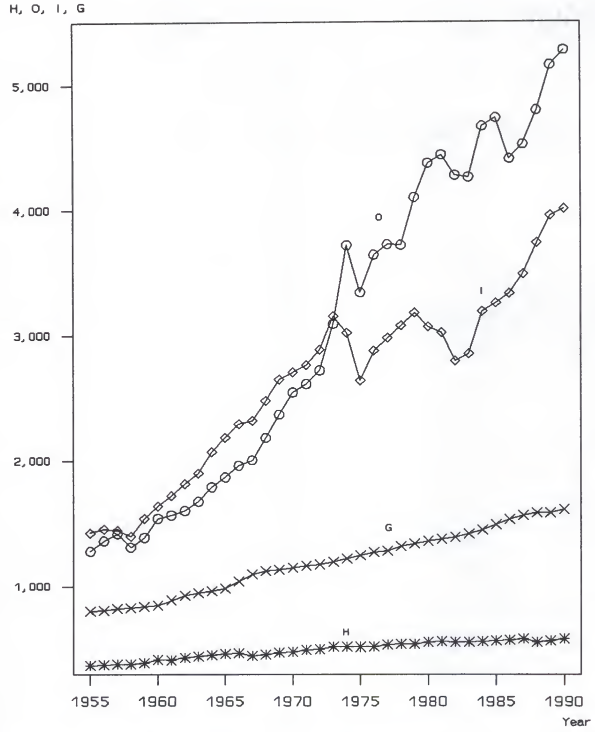
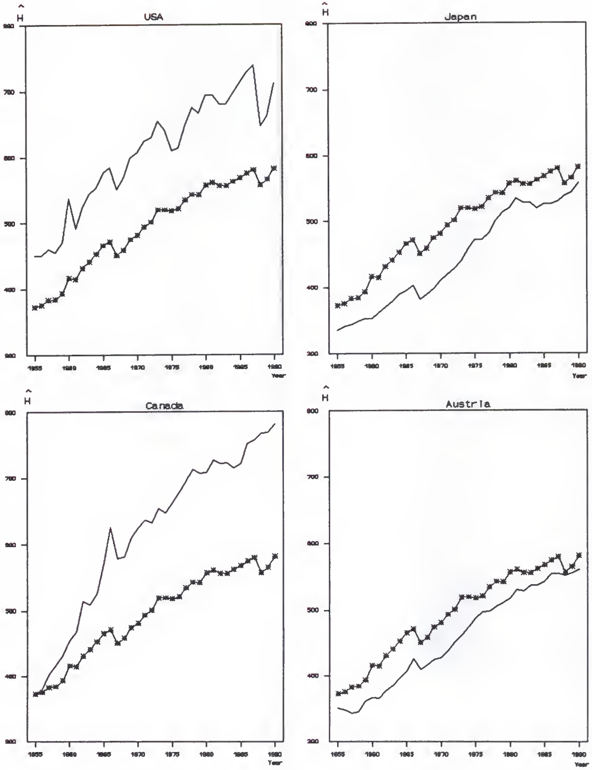


Figure 4.2 - Average Level of Human Capital ($\hat{H}_{OECD}$), International Openness (O_{OECD}), Investment (I_{OECD}) and Government (G_{OECD}) Expenditures in the 22 OECD Countries, 1955-1990

Figure 4.3 Comparing Countrywise Levels of Human Capital ($\hat{H}_i$, i=1 to 22) and Average Level of Human Capital ($\hat{H}_{OECD}$) in the 22 OECD Countries, 1955-1990

——————————— $\hat{H}_i$

—*——*——*——*— $\hat{H}_{OECD}$


USA
Japan
Canada
Austria
Year
Year
Year
Year

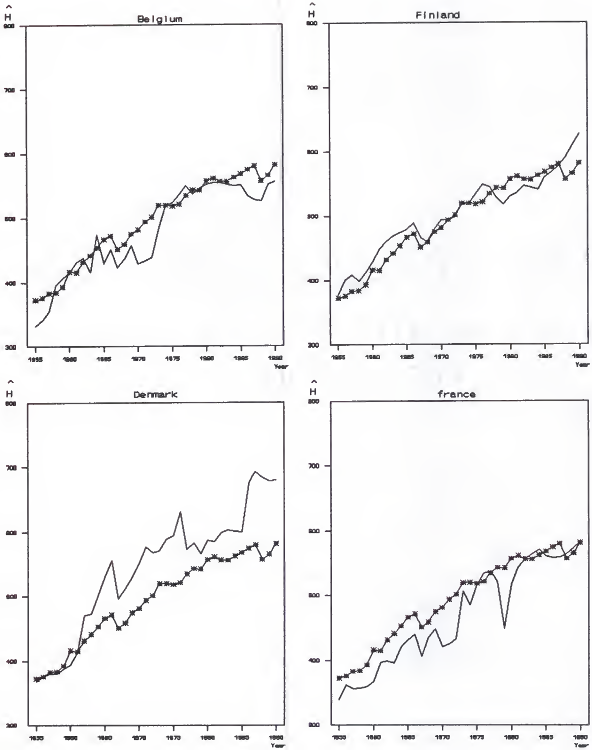


Figure 4.3 (Contd)

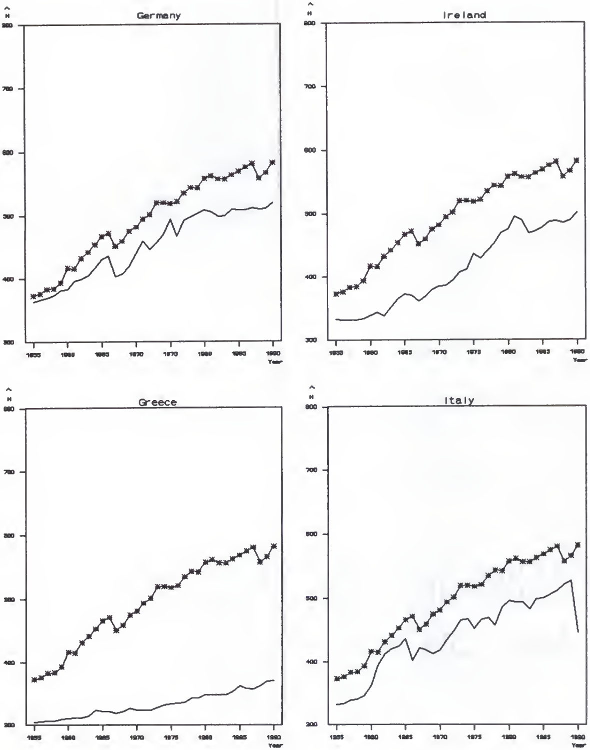


Figure 4.3 (Contd)

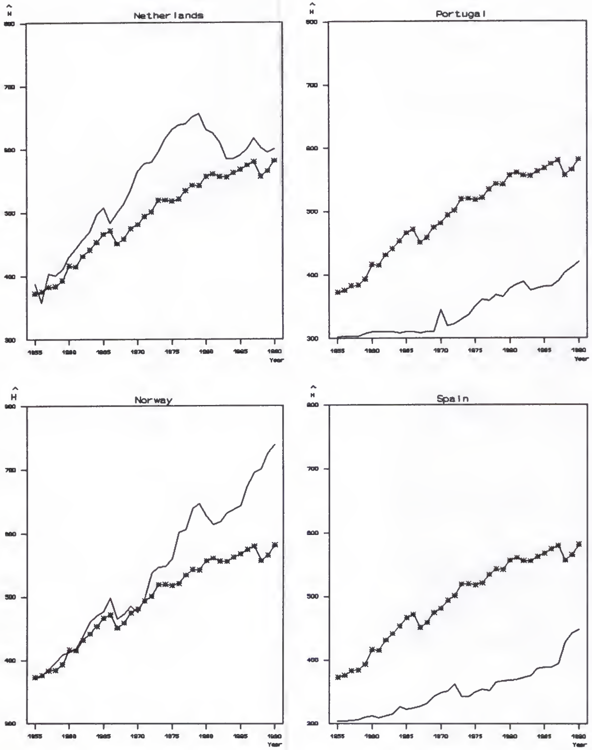


Figure 4.3 (Contd)

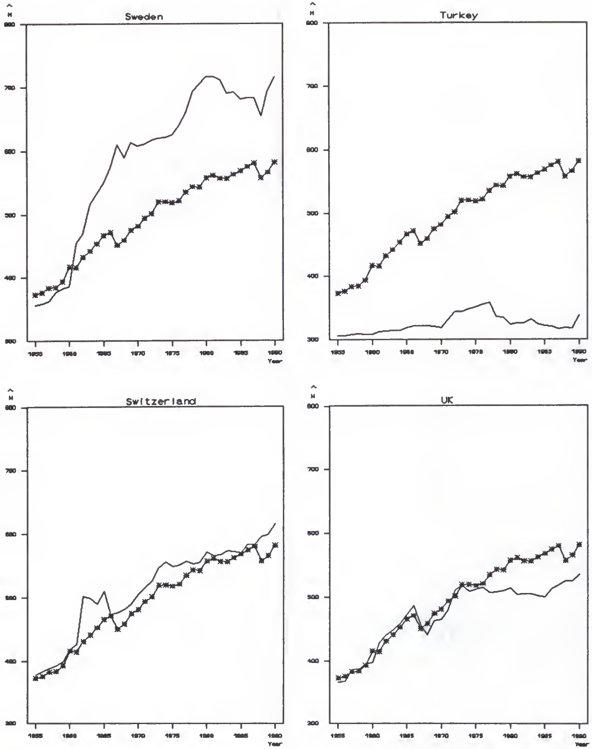


Figure 4.3 (Contd)

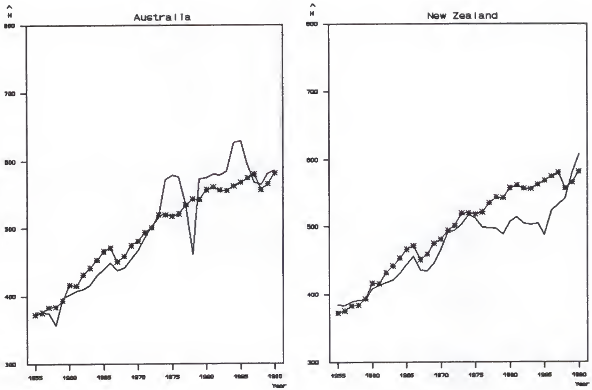


Figure 4.3 (Contd)

Table 4.5 Levels of Observed Income (Y_i, i=1 to 22) in the 22 OECD Countries, 1955-1990

Year	USA	Canada	Japan	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland
1	2	3	4	5	6	7	8	9	10	11	12
1955	9593	7012	2125	3921	5094	5453	4598	4944	5185	1688	2969
1956	9584	7459	2260	4061	5208	5572	4675	5267	5444	1819	2896
1957	9530	7363	2401	4296	5294	5780	4666	5477	5667	1936	2861
1958	9278	7225	2511	4458	5172	5837	4595	5550	5814	2007	2843
1959	9718	7330	2706	4605	5307	6349	4910	5685	6196	2064	3030
1960	9776	7288	3033	5176	5583	6751	5367	6013	6637	2088	3184
1961	9835	7298	3436	5420	5841	7134	5755	6287	6888	2312	3348
1962	10234	7645	3643	5512	6104	7505	5825	6608	7099	2330	3482
1963	10514	7914	3983	5718	6305	7394	5911	6869	7209	2574	3632
1964	10928	8284	4449	6015	6687	8124	6233	7279	7641	2798	3787
1965	11492	8709	4600	6178	6860	8433	6607	7540	7999	3066	3862
1966	11999	9142	5041	6475	7027	8559	6690	7893	8088	3181	3862
1967	12160	9279	5547	6636	7252	8775	6752	8203	8001	3316	4014
1968	12555	9635	6223	6887	7509	9030	6837	8498	8479	3550	4355
1969	12806	10034	6842	7207	7965	9607	7522	9062	9080	3907	4657
1970	12725	10175	7500	7565	8453	9675	8247	9621	9557	4234	4884
1971	13041	10665	7700	7905	8686	9861	8358	9897	9695	4516	4822
1972	13632	11192	8224	8351	9067	10348	8861	10177	10020	4883	5028
1973	14226	11917	8769	8746	9681	10628	9425	10608	10433	5235	5596
1974	13909	12298	8503	9047	10092	10417	9799	10781	10291	4971	5701
1975	13479	12348	8572	8981	9793	10185	9767	10467	10127	5198	5756
1976	14087	12996	8871	9423	10341	10898	9510	10945	10784	5414	5805
1977	14655	13246	9193	9851	10428	11014	9466	11098	11097	5511	6243
1978	15303	13691	9549	9806	10695	11085	9554	11365	11444	5786	6628
1979	15408	14191	9982	10281	10955	11426	10358	11708	11980	5894	6806
1980	15097	14231	10292	10586	11354	11234	10985	11798	12013	5895	6785
1981	15339	14681	10602	10456	10967	10997	11013	11758	11862	5877	6964
1982	14612	13799	10849	10508	11108	11383	11339	11981	11706	5936	7023
1983	15039	14176	11042	10741	11009	11682	11577	11921	11988	5899	6875
1984	16154	15047	11456	10918	11295	12314	11841	12012	12337	5963	7084
1985	16559	15695	12004	11172	11324	12884	12128	12186	12543	6184	7215
1986	16885	16155	12240	11306	11552	13428	12283	12505	12832	6221	7144
1987	17332	16759	12703	11510	11910	13364	12745	12753	13006	6197	7423
1988	17975	17393	13475	11968	12534	13376	13499	13222	13544	6404	7753
1989	18354	17690	14045	12378	13097	13579	14371	13664	13937	6622	8406
1990	18399	17415	14836	12858	13600	13801	14219	13934	14498	6679	9080

Table 4.5 (Contd)

Year	Italy	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	Turkey	UK	Australia	New Zealand
13	14	15	16	17	18	19	20	21	22	23	24
1955	3645	5365	5112	1543	2669	6549	8310	1429	5968	7312	6834
1956	3773	5626	5214	1602	2850	6702	8754	1410	6020	7155	6736
1957	3904	5682	5361	1678	2943	6840	8903	1655	6105	7140	6970
1958	4042	5424	5391	1685	3056	6954	8443	1752	6092	7485	6893
1959	4277	5637	5501	1774	2940	7282	9026	1664	6314	7807	7007
1960	4636	6122	5665	1869	3196	7492	9639	1604	6548	7879	7920
1961	4993	6269	5914	2004	3573	7857	10328	1613	6690	7678	8025
1962	5285	6445	6141	2077	3912	8129	10581	1651	6697	8089	8109
1963	5580	6616	6433	2197	4207	8495	10849	1794	6927	8485	8340
1964	5657	7158	6727	2253	4413	9025	11258	1798	7276	8981	8634
1965	5765	7431	7029	2415	4692	9285	11425	1793	7378	8955	8991
1966	6085	7562	7296	2479	4988	9370	11580	1970	7482	9282	9084
1967	6499	7887	7667	2659	5163	9603	11794	2000	7665	9503	8664
1968	6863	8335	7739	2934	5429	9893	12062	2089	7934	10240	8577
1969	7270	8778	8035	3017	5864	10295	12612	2142	8001	10556	9094
1970	7669	9228	8129	3323	6017	10643	13274	2179	7695	10917	9352
1971	7689	9493	8433	3759	6173	10621	13681	2343	8312	11039	9686
1972	7815	9711	8827	3998	6653	10808	13945	2441	8963	11288	9966
1973	8383	10096	9174	4479	7116	11194	14254	2454	9410	11675	10656
1974	8788	10411	9593	4704	7454	11548	14454	2646	9156	11517	11159
1975	8354	10291	9915	4363	7389	11825	13228	2832	9014	11616	10468
1976	8909	10739	10590	4526	7531	11873	13058	2998	9300	11865	10580
1977	9104	10939	10872	4733	7589	11528	13388	3102	9550	11750	9968
1978	9371	11147	11288	4775	7544	11613	13423	3019	9912	12279	9924
1979	9930	11325	11807	4914	7458	12073	13825	2930	10220	12332	10259
1980	10445	11323	12249	5048	7495	12290	14653	2853	10028	12622	10260
1981	10382	11105	12290	5092	7319	12165	14704	2843	9933	12828	10747
1982	10349	10891	12257	5194	7351	12274	14446	2847	10126	12168	10686
1983	10369	11005	12779	5105	7378	12479	14514	2885	10536	12840	10805
1984	10649	11317	13557	4952	7403	12999	14722	2996	10781	13349	11322
1985	10895	11570	14227	5026	7547	13313	15209	3059	11137	13662	11324
1986	11199	11736	14821	5250	7820	13558	15657	3281	11580	13755	11430
1987	11547	11747	14918	5615	8321	13931	15934	3423	12151	14190	11498
1988	12021	11987	14752	5990	8809	14231	16320	3395	12751	14659	11481
1989	12367	12434	14647	6281	9305	14534	16799	3370	13050	14904	11811
1990	12557	12868	14891	6525	9664	14495	17007	3711	13068	14304	11540

Table 4.6 Levels of Estimated Income ($\hat{Y}_i$, $i=1$ to 22) in the 22 OECD Countries, 1955-1990

Year	USA	Canada	Japan	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland
1	2	3	4	5	6	7	8	9	10	11	12
1955	8797.69	7116.97	4038.78	5327.55	5671.12	6032.36	6374.98	5683.44	6628.47	3531.65	4623.24
1956	8637.34	7824.74	4148.52	5207.65	5946.81	6263.32	6490.69	6121.38	6694.42	3639.48	4398.68
1957	8436.04	7544.98	4307.19	5421.78	5934.50	6506.80	6454.31	6249.57	6799.50	3713.47	4248.08
1958	8218.77	7153.03	4255.03	5519.17	5648.53	6292.25	6357.49	6315.97	6894.39	3790.09	4227.04
1959	8628.63	7239.31	4429.87	5600.65	5936.59	7144.40	6721.90	6402.74	7326.36	3856.12	4575.81
1960	8483.06	7050.75	4755.62	6234.38	6190.28	7613.40	7347.89	6742.16	7772.61	3947.30	4557.86
1961	8521.46	7050.09	5273.65	6370.57	6522.87	7796.35	7725.27	6932.05	7955.89	4147.62	4723.25
1962	8935.43	7316.07	5271.99	6320.02	6693.47	8272.63	7637.64	7174.07	8138.33	4148.63	4905.94
1963	9133.11	7418.17	5581.54	6418.88	6812.69	7867.55	7438.75	7335.22	8148.59	4354.87	5074.60
1964	9332.10	7721.68	5944.82	6831.17	7371.19	8922.02	7872.45	7782.97	8631.33	4638.66	5288.94
1965	9856.74	8231.13	5957.18	6908.21	7410.78	9235.22	8457.64	7917.41	8968.40	4899.57	5504.39
1966	10299.42	8642.58	6295.01	7264.04	7709.33	9219.50	8445.61	8252.59	8854.63	4802.35	5334.12
1967	10331.44	8437.64	6862.08	7269.07	7789.29	9410.94	8286.44	8457.28	8467.51	4856.57	5357.39
1968	10532.81	8618.33	7531.19	7443.00	7893.71	9647.26	8272.43	8750.92	8977.94	5035.37	5780.74
1969	10636.95	8995.37	8094.23	7690.30	8364.08	10436.75	8887.99	9331.40	9571.26	5470.91	6275.80
1970	10203.61	8879.80	8851.45	8195.68	8744.25	10588.66	10112.14	9611.99	10022.87	5707.66	6296.25
1971	10547.50	9205.15	8838.86	8342.88	8725.22	10695.33	10128.13	9811.41	10035.28	5870.57	6383.02
1972	10819.83	9474.53	9262.94	8763.83	8817.44	11167.47	9979.98	10070.31	10222.53	6170.95	6739.54
1973	11236.85	10063.55	9930.74	9174.50	9457.27	11697.15	10612.11	10644.95	10495.48	6933.55	7227.47
1974	10873.34	10643.88	9536.70	9358.21	10062.62	11292.97	11927.11	10790.15	9898.08	6254.53	7311.30
1975	9925.54	10595.93	9161.95	8856.20	9359.77	10365.30	11790.14	9810.48	9569.17	6301.13	6675.96
1976	10536.42	10883.38	9357.72	9467.20	9835.78	11502.90	10532.63	10483.50	10311.68	6358.53	7080.00
1977	11149.81	10963.09	9512.81	9796.58	9897.80	11375.29	10394.50	10533.35	10328.23	6391.36	7556.63
1978	11651.37	11043.70	9836.68	9553.50	10094.09	11341.32	9957.54	10500.77	10603.72	6584.79	7946.65
1979	11524.01	11791.15	10292.94	9990.30	10267.71	11673.53	11196.24	10934.63	11394.51	6857.86	8509.57
1980	10894.44	11922.47	10258.34	10442.76	10605.87	11036.71	12143.36	11053.39	11350.51	6713.87	7962.20
1981	11217.49	12640.43	10409.11	9974.28	9685.97	10338.71	11730.88	10656.76	10760.96	6370.28	8208.75
1982	10297.43	11176.82	10368.57	9584.59	9735.14	10872.61	12005.92	10852.26	10453.89	6224.60	8339.24
1983	10716.03	11505.48	10207.74	9565.95	9426.59	10877.70	12084.13	10472.86	10825.97	6230.87	7930.94
1984	12233.18	12068.64	10547.37	10109.63	9865.05	11701.00	12097.55	10438.05	11078.58	6155.06	7981.83
1985	12341.98	12587.89	10923.03	10279.05	9596.10	12315.43	12218.77	10596.14	11095.94	6381.61	7739.18
1986	12431.93	12995.84	11149.17	10333.99	9737.85	13001.85	12098.57	10993.89	11303.91	6152.73	7609.92
1987	12713.03	13706.89	11673.59	10465.21	10165.98	12496.88	12614.49	11340.79	11405.95	5922.22	7403.36
1988	12901.95	14384.36	12683.65	10963.91	10864.08	12157.62	13618.65	11851.40	11920.22	6357.50	7361.64
1989	13126.17	14823.41	13458.70	11311.00	11700.46	12447.88	15031.49	12241.81	12404.95	6414.57	8116.47
1990	12992.92	14176.48	14379.56	11864.18	12125.36	12111.65	14497.35	12442.52	12945.13	6372.22	8777.88

Table 4.6 (Contd)

Year	Italy	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	Turkey	UK	Australia	New Zealand
13	14	15	16	17	18	19	20	21	22	23	24
1955	5514.50	6761.07	6879.14	3496.76	4154.43	7108.71	7561.72	3414.31	6425.34	7567.93	7558.55
1956	5616.18	7047.60	6901.59	3541.06	4273.60	7187.11	8070.87	3393.72	6428.86	7098.84	7356.73
1957	5759.19	7145.70	7023.27	3662.69	4347.88	7400.04	8292.34	3452.85	6470.64	7138.92	7548.77
1958	5839.59	6508.60	7118.70	3647.72	4437.20	7423.03	7270.51	3573.08	6356.64	7580.42	7386.45
1959	6055.31	6758.36	7029.04	3677.37	4195.03	7713.27	8003.70	3521.09	6535.10	7766.33	7406.19
1960	6442.15	7370.55	7091.86	3842.95	4428.09	8142.62	8941.58	3497.43	6859.13	8093.10	7724.47
1961	6776.73	7479.49	7335.40	3936.88	4744.29	8275.88	9879.31	3535.21	6944.07	7427.64	7948.30
1962	7045.08	7496.60	7518.77	4044.50	5037.56	8484.43	10049.39	3559.44	6867.64	8044.59	7727.73
1963	7280.21	7540.08	7818.13	4051.94	5183.93	8776.99	10202.12	3619.89	6977.25	8298.72	8039.51
1964	7073.67	8286.94	8047.35	4192.83	5369.73	9359.02	10650.08	3615.21	7505.48	9141.70	8480.51
1965	6862.33	8298.91	8490.24	4344.59	5695.40	9694.52	10383.50	3607.71	7540.31	9047.85	9035.77
1966	7026.56	8446.75	8763.60	4371.80	5956.59	9707.09	10352.28	3783.92	7569.48	9237.11	9373.24
1967	7415.75	8679.98	9267.23	4551.64	5981.79	9820.19	10538.43	3792.00	7842.00	9359.99	8423.46
1968	7725.67	9076.96	8927.22	4663.85	6154.58	10005.72	10613.29	3857.47	8048.96	10072.69	7855.90
1969	8080.35	9322.70	8773.81	4697.28	6550.74	10495.52	11000.04	3871.74	8022.79	10094.58	8451.74
1970	8285.84	9858.17	9703.44	5133.54	6564.79	11195.16	11968.42	3971.13	8112.43	10313.45	8635.92
1971	8099.61	9854.17	10290.76	5353.00	6488.51	10799.98	12288.69	4022.07	8151.34	10055.65	8873.53
1972	8188.95	9620.69	9792.39	5674.61	6926.45	10739.39	12281.15	4018.74	8206.72	9960.23	9102.80
1973	8749.94	9961.44	10575.86	6050.50	7326.57	10806.09	12471.45	4111.00	8898.46	10710.92	10378.71
1974	9094.63	10031.39	11434.80	6023.27	7704.65	11538.59	12733.36	4330.91	8739.38	10375.24	11628.59
1975	8082.09	9388.14	11898.73	5348.78	7520.06	11968.17	10492.99	4575.98	8402.93	10265.50	9477.74
1976	8719.65	9692.64	12698.49	5499.49	7522.21	12012.85	10345.06	4635.13	8808.67	10668.22	9654.53
1977	8582.75	9953.71	12620.92	5937.58	7377.18	11193.17	10510.39	4753.86	8833.51	10157.11	9173.52
1978	8659.04	10099.50	11452.81	6080.71	7181.22	10659.18	10886.45	4401.60	8935.18	10924.31	8669.24
1979	9040.00	10094.41	11836.86	6338.60	7117.27	11524.19	11772.88	4373.65	9105.01	10836.91	9161.81
1980	9614.07	10059.33	12499.27	6646.20	7231.59	12007.89	12898.39	4493.28	8561.56	11264.17	8887.32
1981	9186.62	9236.36	12431.43	6720.56	6932.34	11323.30	12464.35	4550.63	8275.17	11672.49	9615.32
1982	9102.17	9197.88	12551.77	6866.36	7012.02	11349.49	12082.08	4472.75	8559.19	10360.03	9792.81
1983	8966.55	9399.59	12512.59	6361.93	6939.45	11364.74	12315.54	4446.91	8916.61	11041.76	10009.04
1984	9382.49	9711.55	13562.74	6030.39	6860.76	11867.01	12676.62	4447.12	9217.27	11559.96	10643.78
1985	9516.06	10044.66	13426.96	6034.15	6991.38	12532.75	13094.06	4573.56	9326.63	11868.55	10347.82
1986	9561.95	9839.58	14580.95	6246.56	7358.05	12415.50	14069.76	4711.67	9413.30	11481.07	10231.82
1987	9830.04	9478.05	14141.08	6313.00	7943.62	12770.99	14695.97	4782.81	9799.56	11820.12	10206.83
1988	10188.1	9696.20	13655.62	6407.80	8555.98	13139.43	15114.09	4678.83	10445.90	12812.30	10172.23
1989	10385.1	10488.43	13175.96	6635.07	9218.02	13906.96	15871.16	4583.14	10691.44	12842.90	11339.54
1990	10422.5	10779.49	12649.94	6878.67	9597.00	13863.07	16119.85	4793.40	10450.70	11730.73	11109.94

Table 4.7 - Average Levels of Observed and Estimated Income Per Capita (Y_{OECD}, $\hat{Y}_{OECD}$) in the 22 OECD Countries, 1955-1990

Year	Observed Income Y_{OECD}	Estimated Income $\hat{Y}_{OECD}$
1	2	3
1955	5603.64	6335.28
1956	5723.63	6389.51
1957	5813.63	6406.68
1958	5798.50	6332.68
1959	6061.19	6573.94
1960	6287.77	6759.70
1961	6497.31	6945.81
1962	6763.09	7155.94
1963	7021.29	7324.48
1964	7380.76	7622.04
1965	7682.17	7846.86
1966	8013.23	8098.39
1967	8232.08	8229.28
1968	8624.72	8532.40
1969	8994.56	8829.64
1970	9216.68	8961.31
1971	9480.43	9076.73
1972	9914.48	9296.54
1973	10402.89	9778.07
1974	10335.40	9653.87
1975	10127.53	9060.21
1976	10562.65	9491.47
1977	10867.58	9682.47
1978	11232.67	9889.26
1979	11497.94	10113.69
1980	11512.11	9979.04
1981	11599.01	9937.19
1982	11398.71	9590.19
1983	11633.87	9715.47
1984	12163.43	10333.14
1985	12495.18	10502.00
1986	12786.72	10656.12
1987	13162.41	10957.08
1988	13699.01	11398.60
1989	14076.57	11770.50
1990	14317.18	11902.49

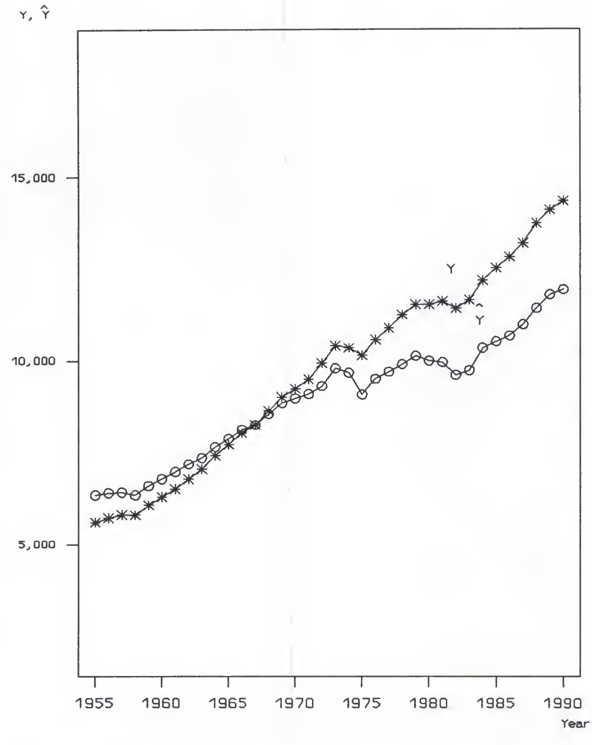


Figure 4.4 - Average Levels of Observed and Estimated Income, Y_{OECD} and $\hat{Y}_{OECD}$, in the 22 OECD Countries, 1955-1990

income and the gap is widening. This gap could be due to the pooling of data which makes the estimation process insensitive to country specific effects.

The values from Tables 4.5 and 4.6 and Figure 4.5 depict the relationship between observed and estimated income for the 22 countries individually. These comparisons indicated that the model underestimates the income of three countries (USA, Canada, Switzerland), overestimates the income for five countries (Greece, Ireland, Norway, Portugal, Turkey), and fits well for the remaining 14 (Japan, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Spain, Sweden, UKD, Australia, New Zealand).

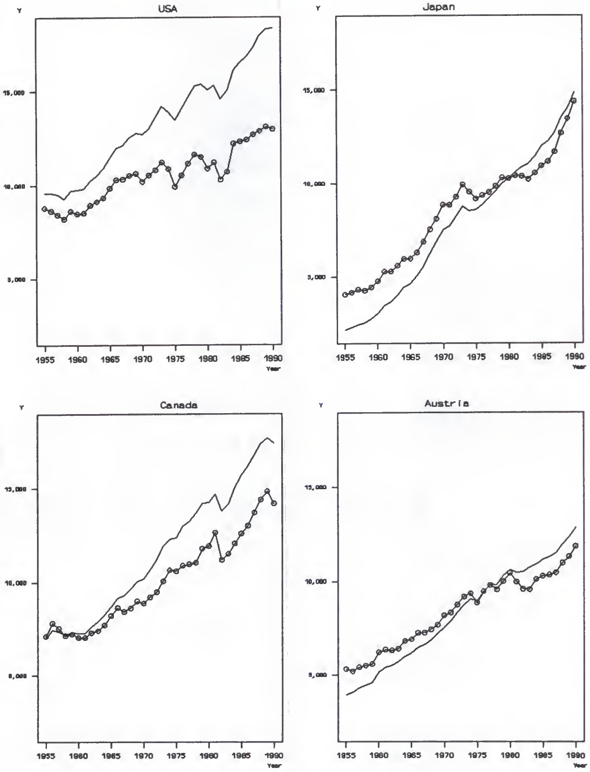
Comparing Figures 4.1, 4.2, and 4.4, it was seen that international openness, investment and government expenditures, in their average levels, had increasing trends. This result also implied that the OECD countries were increasing their trading activities and investments over time. Yet again, comparing values from Tables 4.6 and 4.7 (Column 3), and Figure 4.6 revealed that the estimated incomes of nine countries (USA, Denmark, Finland, France, Germany, Norway, Sweden, Switzerland, Australia) were above-average, six countries (Greece, Ireland, Italy, Portugal, Spain, Turkey) were below-average, and seven countries (Canada, Japan, Austria, Belgium, Netherlands, UKD, New Zealand) moved closely with the average of the group of 22 countries.

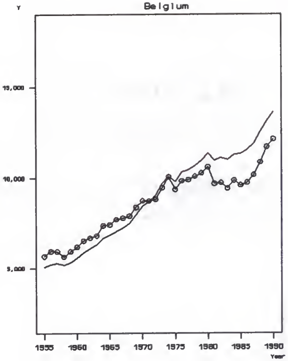
Figure 4.7 depicts the relationship between Y_{OECD} and $\hat{H}_{OECD}$ (Table 4.7, column 3 and Table 4.4, column 2, respectively) as a positive and increasing one implying that human capital did have a significant and positive effect on per capita income for the 22 OECD countries. Similarly, using the values in Tables 4.3 and 4.6, Figure 4.8 depict

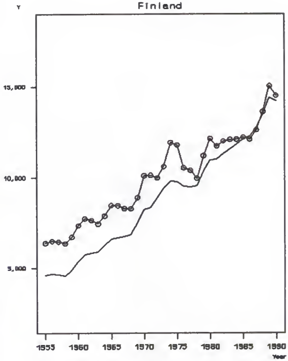
Figure 4.5 Comparing Countrywise Levels of Observed Income (Y_i, $i=1$ to 22) and Estimated Income ($\hat{Y}_i$, $i=1$ to 22) in the 22 OECD Countries, 1955-1990

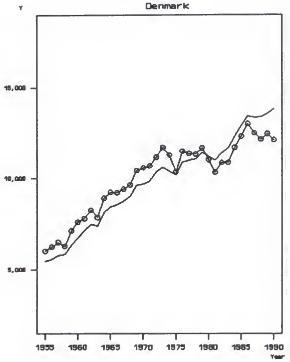
Y_i

$\hat{Y}_i$


USA
Japan
Canada
Austria
Y
15,000
10,000
5,000
1955
1960
1965
1970
1975
1980
1985
1990
Year







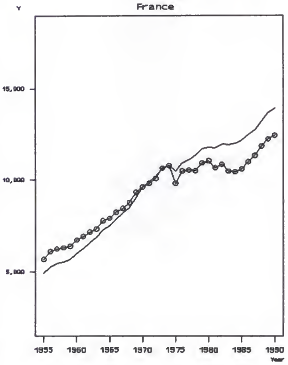
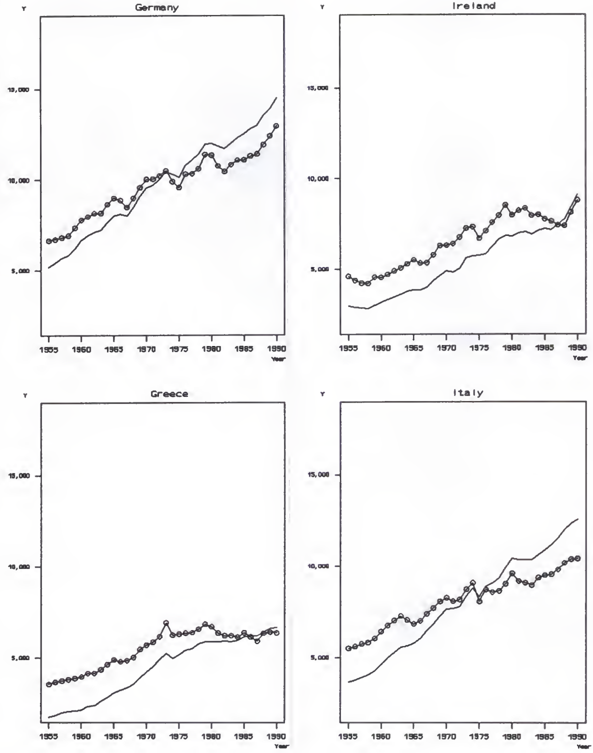


Figure 4.5 (Contd)



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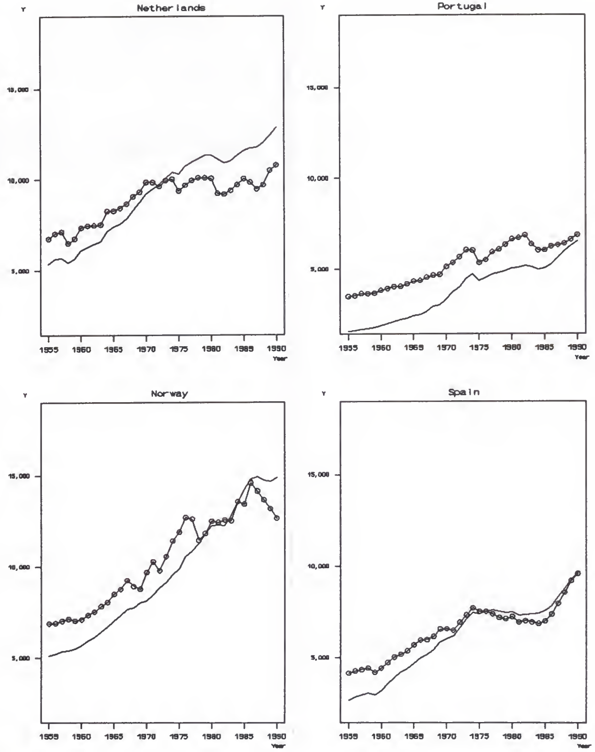


Figure 4.5 (Contd)

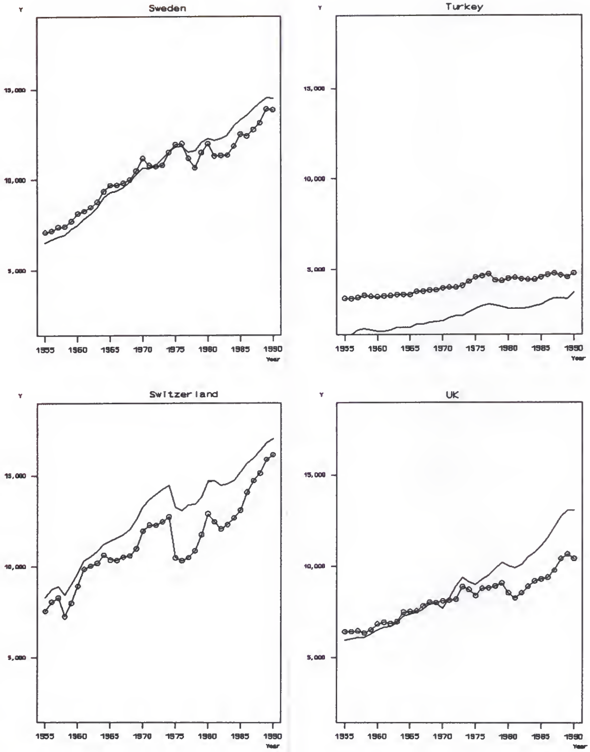


Figure 4.5 (Contd)

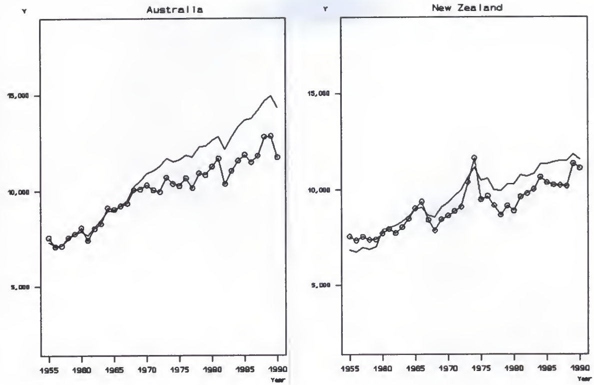
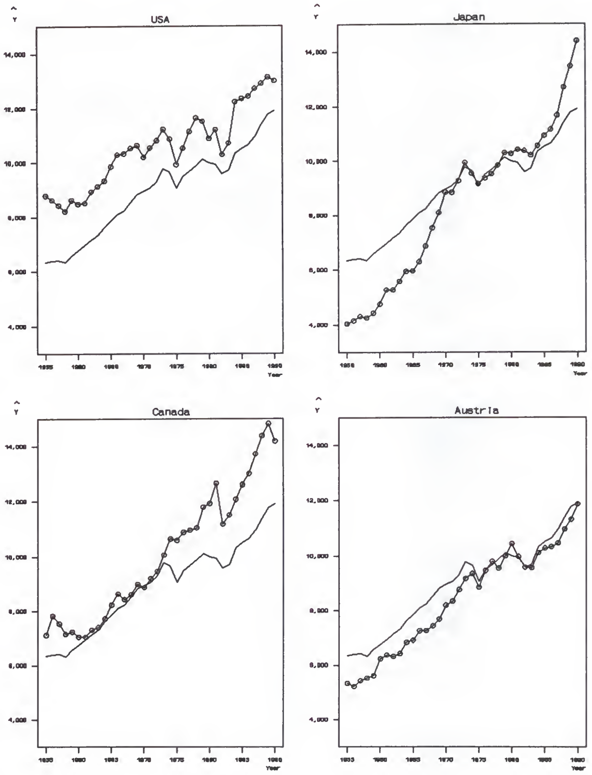


Figure 4.5 (Contd)

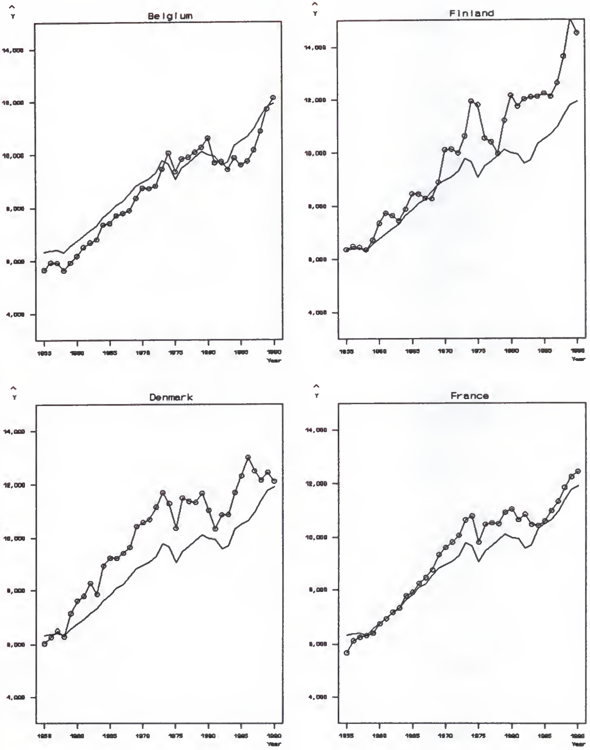
Figure 4.6 Comparing Countrywise Levels of Estimated Income ($\hat{Y}_i$, i=1 to 22) and Average Level of Estimated Income ($\hat{Y}_{OECD}$) in the 22 OECD Countries, 1955-1990

$\hat{Y}_{OECD}$

$\hat{Y}_i$



USA
Japan
Canada
Austria
Year



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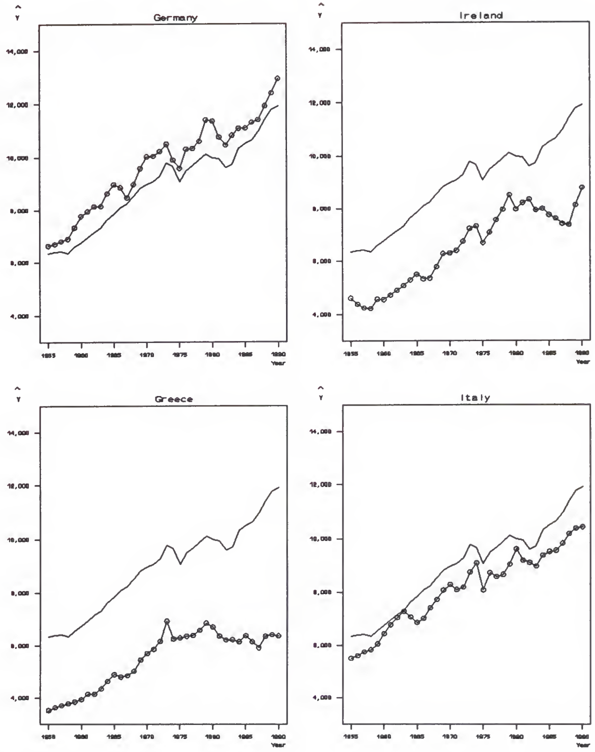

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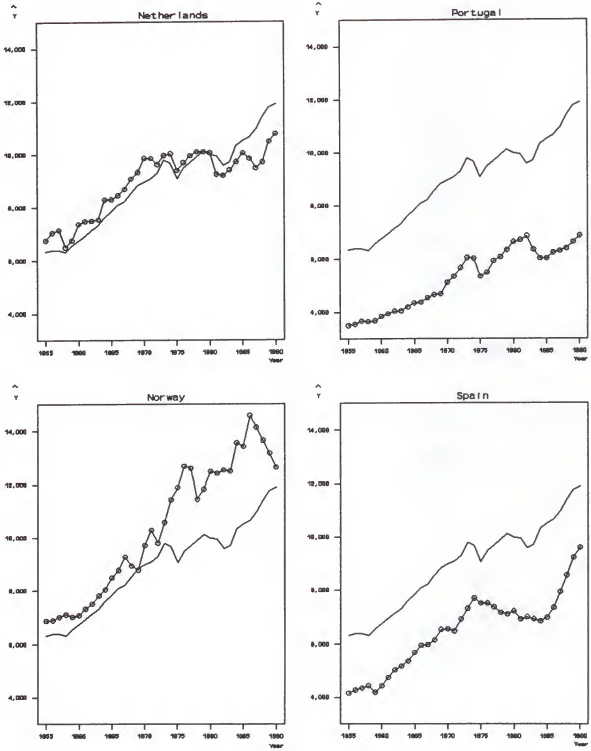


Figure 4.6 (Contd)

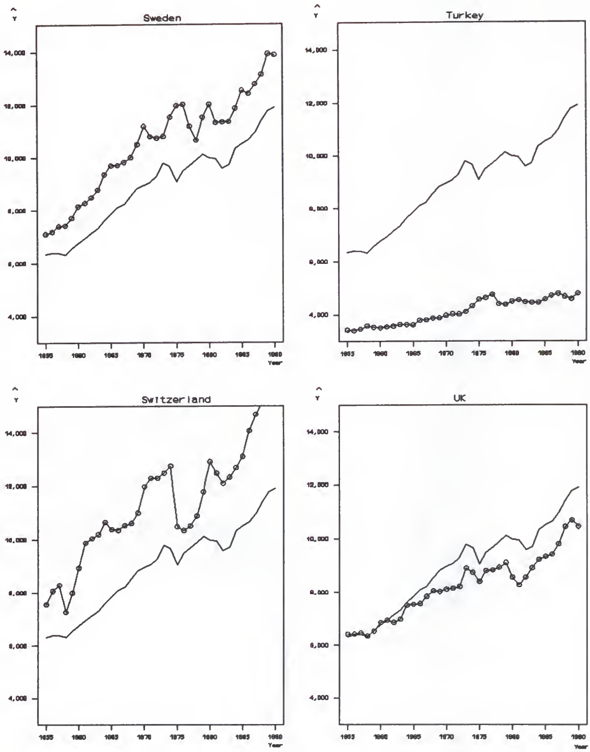


Figure 4.6 (Contd)

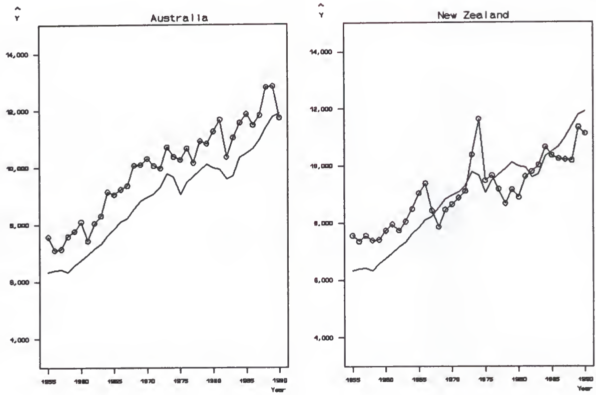


Figure 4.6 (Contd)

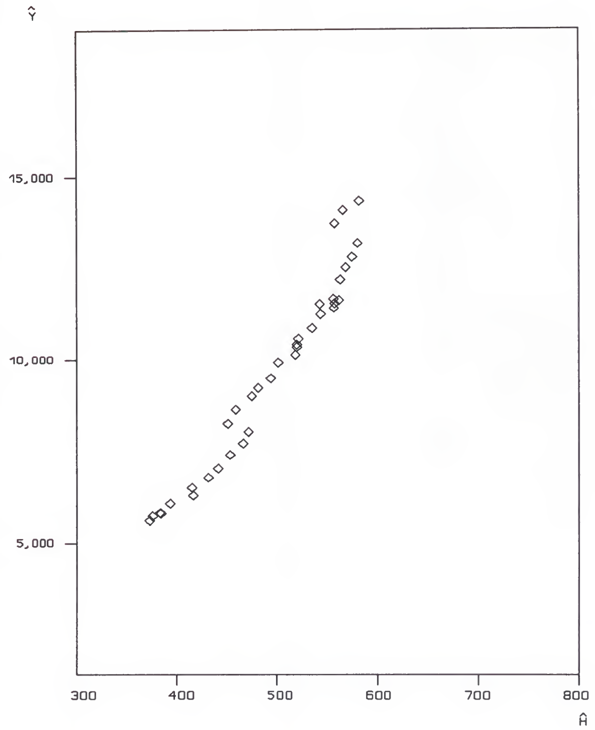
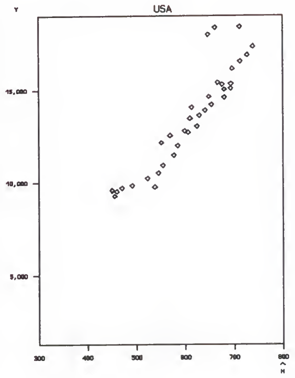
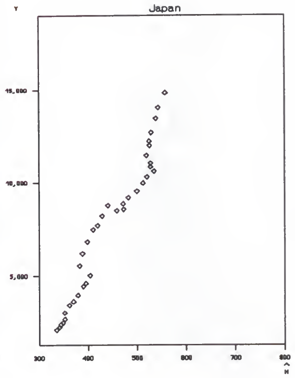


Figure 4.7 - Relationship Between Average Levels of Observed Income ($\hat{Y}_{OECD}$) and Human Capital ($\hat{H}_{OECD}$) in the 22 OECD Countries, 1955-1990

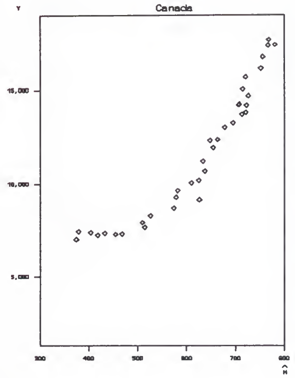
Figure 4.8 Countrywise Relationship Between Levels of Observed Income (Y_i, $i=1$ to 22) and Human Capital ($\hat{H}_i$, $i=1$ to 22) in the 22 OECD Countries, 1955-1990



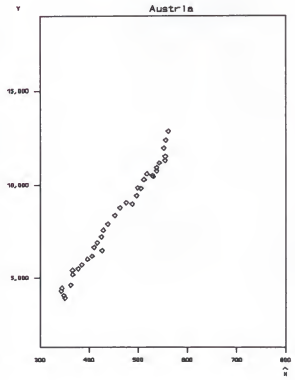
USA
Y
15,000
10,000
5,000
300
400
500
600
700
800



Japan
Y
15,000
10,000
5,000
300
400
500
600
700
800



Canada
Y
15,000
10,000
5,000
300
400
500
600
700
800



Austria
Y
15,000
10,000
5,000
300
400
500
600
700
800

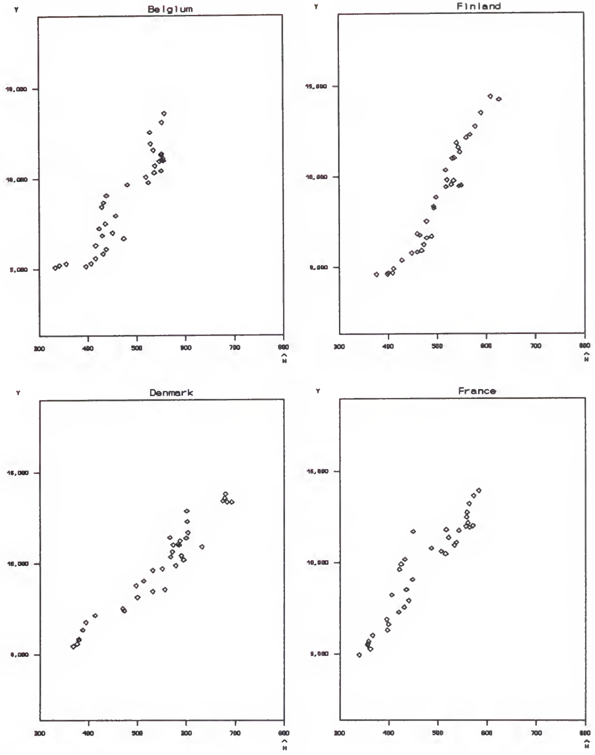
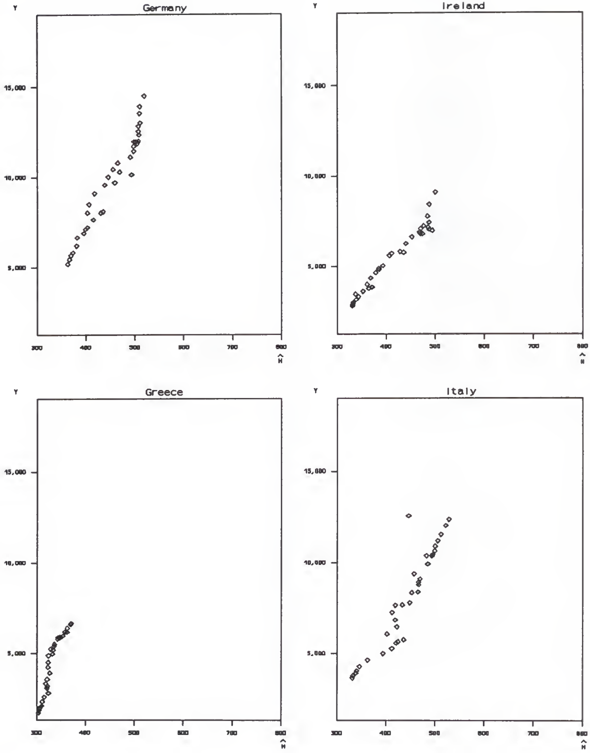


Figure 4.8 (Contd)



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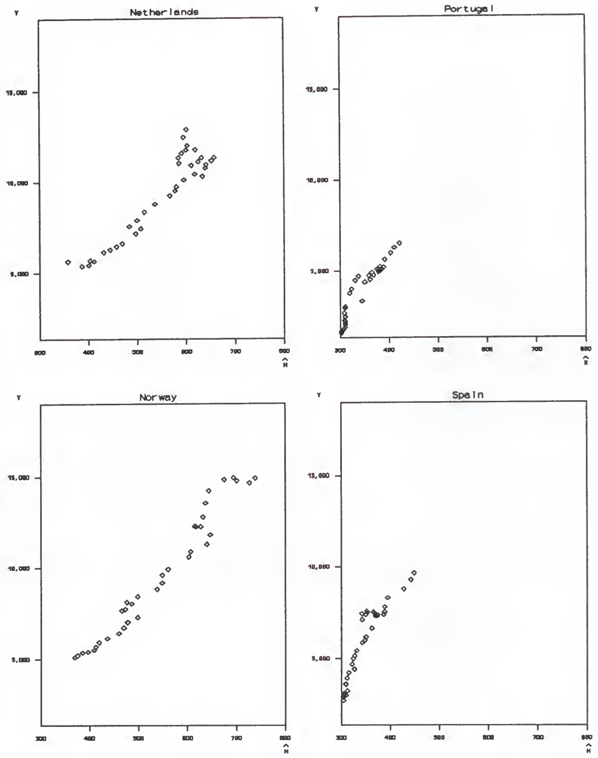


Figure 4.8 (Contd)

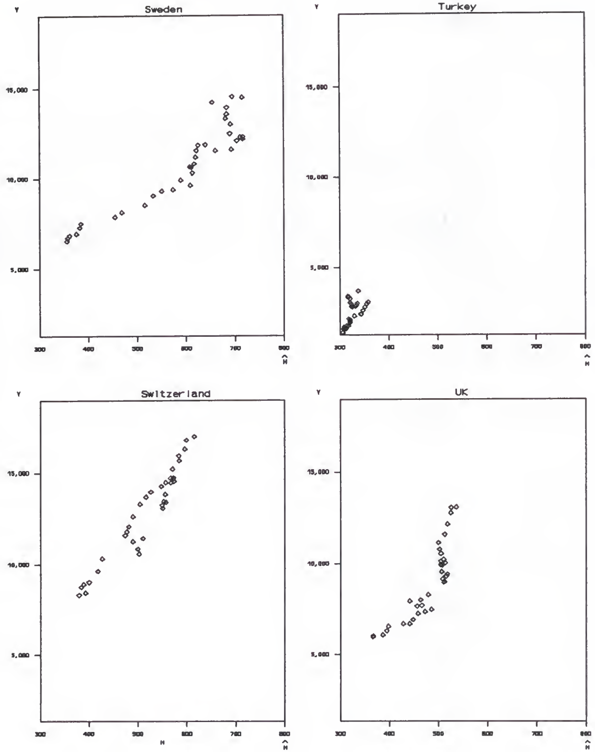
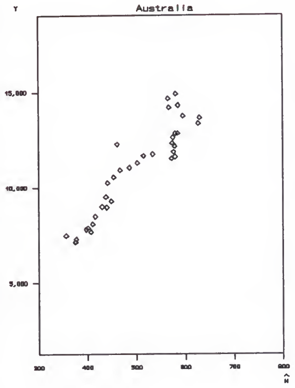


Figure 4.8 (Contd)



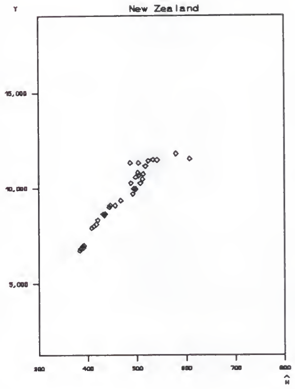


Figure 4.8 (Contd)

the relationship between observed income and human capital for the 22 countries individually. This analysis showed that all countries showed clear evidence of a positive relationship between income and human capital.

The analyses of the individual countries (Table 4.8) revealed that four countries (United States, Denmark, Norway, and Sweden) were the only ones that had above-average human capital and income; six countries (Greece, Ireland, Italy, Portugal, Spain, and Turkey) had below-average human capital and income; and only three countries (Belgium, UK, and New Zealand) had levels of human capital and income that tracked the average levels reasonably well.

4.6 Summary

From the analyses in Sections 4.4 and 4.5 above the major points to note were: (i) the data fits the model reasonably well; (ii) all four determinants of income had positive effects; (iii) both observed and estimated income for the 22 OECD countries was increasing over time; (iv) estimated income and human capital have a significant positive relationship; (v) human capital had the greatest positive effect on income; (v) the income elasticity with respect to human capital was positive and greater than those with respect to openness, investment and government expenditures; and (vi) all four determinants depict an increasing trend. Therefore, the results from this study imply that human capital contributes positively to economic growth and is a key determinant of income. These results correspond to the contemporary evidence presented by Barro (1991), Mankiw et al. (1992), Tallman and Wang, (1992), Lucas (1988, 1993), and Romer

(1990) who concluded that human capital accumulation was vital to the growth of an economy.

Table 4.8 Summary of Cross-Country Analyses for the 22 OECD Countries, 1955-1990

	$\hat{Y}_i$ above $\hat{Y}_{OECD}$	$\hat{Y}_i$ below $\hat{Y}_{OECD}$	Tracks $\hat{Y}_{OECD}$
$\hat{H}_i$ above $\hat{H}_{OECD}$	Denmark Norway Sweden USA		Canada Netherlands
$\hat{H}_i$ below $\hat{H}_{OECD}$	Germany	Greece Ireland Italy Portugal Spain Turkey	Austria Japan
Tracks $\hat{H}_{OECD}$	Australia Finland France Switzerland		Belgium New Zealand UK

CHAPTER 5

INEQUALITY IN THE OECD COUNTRIES

Historically, inequality measures have been used to study convergence (or divergence). Basic statistical tools such as graphs (e.g., histograms and Lorenz curves), measures of dispersion (e.g., variance and coefficient of variation), and indices (e.g., gini coefficient and Theil's inequality index) have been used to analyze income inequality between and among groups. Using these tools, researchers have tried to determine if two income groups grew closer (convergence) or moved away from each other (divergence).

5.1 Graphical Inequality

A histogram may be used to depict a frequency distribution of incomes of people at various levels. The Lorenz curve depicts a relationship between cumulative shares of income (on the vertical axis) against cumulative population shares (on the horizontal axis). Since these shares vary between 1 and 0, a person with all the income would be along the vertical axis, and if incomes were equal then the curve is a 45^0 diagonal.

5.2 Inequality via Measures of Dispersion

The variance of n observations or income values, y_i, with mean μ can be written as

$$(\frac{1}{n}) \sum_{i=1}^{n} (y_i-\mu)^2$$

The square root of the variance is the standard deviation which could also be used as a measure of inequality. Dividing the standard deviation by the mean (μ) yields the coefficient of variation.

5.3 Inequality Indices

The Gini coefficient (G) is computed based on the Lorenz curve

$$G = \frac{1}{2n^2\mu} \sum_{i=1}^{n}\sum_{j=1}^{n} |y_i - y_j|.$$

In graphical terms, the Gini coefficient measures the ratio of the area between the diagonal and the Lorenz Curve to the total area beneath the diagonal.

Theil's income inequality index or entropy index is based on an information measure developed by Shannon (1949). Shannon's measure determines the information content in any given signal. Theil (1967) expands on this tool to measure change in the posterior distribution associated with a given signal. In terms of income inequality, the objective is to determine whether the information regarding a country can be used to predict the level of income. This index is described in detail later in this chapter.

5.4 Properties of Inequality Index

Anand and Kanbur (1993) present a formalization of the Kuznets process, a general analysis of distributional change under this process, and derive the functional forms of and conditions for a turning point in the inequality-development relationship for six commonly used indices of inequality. They used data on a cross-section of 60 developing and developed countries to estimate the functional form appropriate for each index. They divided the countries into regions or sectors. Assuming that during the course of development, the population is seen as shifting from a low-mean income and low-inequality sector to a high-mean income and high-inequality sector, the sectoral mean incomes and inequality levels remaining unchanged over time, they found that the estimated functional forms on the cross-section data rejected the formalization of the Kuznets process. If the Kuznets process is being invoked as the theoretical underpinning of the inequality-development relationship, the right index must be used with the right functional form for estimation purposes.

Four properties for a consistent inequality measure are (Livada, 1991): symmetry, mean independence, population homogeneity, and the Pigou-Dalton condition. Symmetry is equivalent to saying that the social aspects of a country are irrelevant in measuring inequality. Mean independence states that if all incomes are raised or lowered in the same proportion, the inequality measure remains invariant. This means that inequality measures depend on relative rather than absolute incomes. According to population homogeneity the inequality does not change when r populations (each containing n individuals) with identical income distributions are combined into a single population.

The Pigou-Dalton condition requires income inequality to increase whenever an income transfer is made from a poor country to a richer country.

5.5 Theil's Inequality Index

Theil's index satisfies the four properties of any inequality measure: symmetry, mean independence, population homogeneity, and the Pigou-Dalton condition. Further, this index yields a statistic and is additively decomposable.

Theil's income inequality measures inequality by taking the logarithm of the ratio of the arithmetic mean income to the geometric mean income. When this measure is applied to per capita incomes of n countries, it can be written as

$$J = \sum_i p_i \log(p_i/y_i) \tag{5.1}$$

where p_i is the world population share of country i, and y_i is its world income share.

An advantage of J is its additive decomposition, that is, if $R_1,\ldots,R_G$ are regions such that each country is in exactly one region, P_g and Y_g are the population and income shares of region R_g: $P_g = \text{sum}_i\, p_i$ and $Y_g = \text{sum}_i\, y_i$, where the summations are over $i \in R_g$, then

$$J_R = \sum_g P_g \log(P_g/Y_g) \tag{5.2}$$

which measures the inequality among regions, while

$$J_g = \sum_{i \in R_g} (p_i/P_g)\log_e[(p_i/P_g)/(y_i/Y_g)] \tag{5.3}$$

measures the inequality among the countries of region R_g. The additive decomposition is then

$$J = J_R + \bar{J}, \qquad where\ \bar{J} = \sum_g P_g J_g \tag{5.4}$$

Thus, total inequality among the n countries equals regional inequality plus the average within-region inequality, the average being a weighted average with the population shares $P_1,\ldots,P_G$ as weights. Note that these weights are identical to those of the regional per capita incomes.

5.6 Inequality in the OECD Countries

The analysis in this section is based on the observed and estimated inequalities computed for the 22 OECD countries during 1955-1990. Using equation (5.1) the observed and estimated income inequalities, J_Y and $J_{\hat{Y}}$, respectively, were computed. For the observed index, J_Y, Summers and Heston (1993) data for income and population were used. Using the population data from the same source and estimated income computed via a latent variable model (Chapter 4, equation 4.24), the estimated inequality, $\hat{J}_{\hat{Y}}$, was computed using equation (5.1).

The results of the computations of observed and estimated income inequality are given by Table 5.1 and depicted in Figure 5.1. At a glance, from Columns 2 and 3 of the table and from the figure, it was seen that the gap between J_Y and $J_{\hat{Y}}$ was quite wide initially and began to lessen over time. Again this could be attributed to the reduction in nonsystematic errors in the process of empirical estimation and the inability of the process to capture country-specific effects. $J_{\hat{Y}}$ decreased initially and then levelled off at a value of 0.03 depicting a pattern of convergence, in terms of income, and indicating that the OECD countries were moving closer as a group.

Table 5.1 - Average Inequality in Observed Income (J_Y), Estimated Income ($J_{\hat{Y}}$), Human Capital ($J_{\hat{H}}$), International Openness (J_O), Investment (J_I) and Government (J_G) Expenditures in the 22 OECD Countries, 1955-1990

Year	Observed Income	Estimated Income	Human Capital	International Openness	Investment Expenditure	Government Expenditure
	J_Y	$J_{\hat{Y}}$	$J_{\hat{H}}$	J_O	J_I	J_G
1	2	3	4	5	6	7
1955	0.1615	0.0462	0.0093	0.3027	0.2189	0.1830
1956	0.1526	0.0424	0.0087	0.2949	0.1901	0.1832
1957	0.1386	0.0372	0.0096	0.2859	0.1490	0.1896
1958	0.1264	0.0342	0.0088	0.3002	0.1350	0.1838
1959	0.1290	0.0380	0.0100	0.2830	0.1497	0.1735
1960	0.1181	0.0331	0.0186	0.2691	0.1221	0.1632
1961	0.1047	0.0280	0.0109	0.2364	0.0952	0.1598
1962	0.1031	0.0306	0.0142	0.2289	0.1024	0.1563
1963	0.0952	0.0291	0.0162	0.2254	0.0946	0.1446
1964	0.0925	0.0288	0.0158	0.2282	0.0887	0.1397
1965	0.0954	0.0322	0.0182	0.2182	0.0986	0.1347
1966	0.0909	0.0319	0.0197	0.2037	0.0875	0.1419
1967	0.0850	0.0287	0.0172	0.2061	0.0757	0.1477
1968	0.0798	0.0272	0.0183	0.2063	0.0717	0.1443
1969	0.0750	0.0259	0.0211	0.2174	0.0714	0.1378
1970	0.0693	0.0228	0.0211	0.2041	0.0656	0.1308
1971	0.0664	0.0240	0.0220	0.1904	0.0693	0.1174
1972	0.0656	0.0240	0.0206	0.1807	0.0697	0.1158
1973	0.0654	0.0235	0.0224	0.1736	0.0654	0.1107
1974	0.0604	0.0208	0.0198	0.1641	0.0554	0.1076
1975	0.0559	0.0171	0.0159	0.1549	0.0463	0.1001
1976	0.0563	0.0189	0.0164	0.1607	0.0474	0.0954
1977	0.0575	0.0201	0.0189	0.1648	0.0485	0.0916
1978	0.0620	0.0246	0.0226	0.1796	0.0671	0.0875
1979	0.0627	0.0250	0.0218	0.1915	0.0682	0.0869
1980	0.0615	0.0229	0.0234	0.1569	0.0657	0.0833
1981	0.0641	0.0246	0.0233	0.1494	0.0740	0.0831
1982	0.0591	0.0212	0.0220	0.1497	0.0645	0.0840
1983	0.0617	0.0231	0.0218	0.1518	0.0682	0.0849
1984	0.0672	0.0300	0.0234	0.1456	0.0869	0.0887
1985	0.0682	0.0298	0.0252	0.1545	0.0832	0.0918
1986	0.0660	0.0292	0.0271	0.1537	0.0777	0.0916
1987	0.0650	0.0297	0.0283	0.1399	0.0795	0.0918
1988	0.0670	0.0313	0.0182	0.1338	0.0856	0.0917
1989	0.0678	0.0332	0.0190	0.1357	0.0922	0.0899
1990	0.0625	0.0324	0.0230	0.1271	0.0907	0.0865

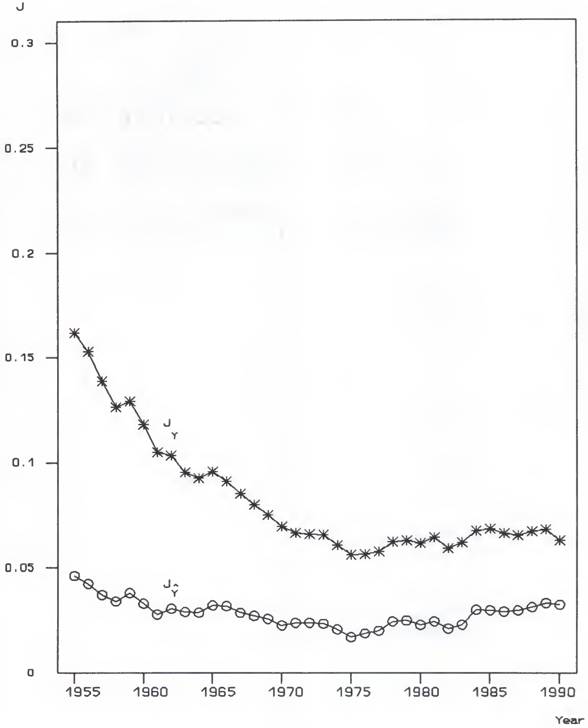


Figure 5.1 - Observed and Estimated Income Inequality (J_Y, $J_{\hat{Y}}$) in the 22 OECD Countries, 1955-1990

Columns 4 to 7 of Table 5.1 give the inequalities in human capital, $J_{\hat{H}}$, international openness, J_O, investment expenditure, J_I, and government expenditure, J_G. The inequalities in human capital and investment expenditure depicted decreasing trends initially and then increased indicating that the OECD countries were converging in terms of these variables initially but have commenced to diverge in terms of human capital and investment expenditure. However, inequality in openness and government expenditure decreased indicating that the OECD countries were converging in terms of these variables.

A graphic comparison of inequalities in income and its determinants of income is given by Figure 5.2. This figure showed that inequality in income and human capital were converging and were almost identical during 1970-1983 and 1986-87. The inequality in openness was larger in value than any other variable and was decreasing over time. Inequality in investment expenditure was decreasing initially and then increased from 1979 onwards. Inequality in government expenditure was decreasing over time and intersected with that of investment expenditure in 1987. These results point to the fact that the convergence in income is contributed by all its determinants. Thus, the low rate of convergence in income could be due to the rapid rate of convergence in openness, a high rate of divergence (from 1979 onwards) in investment expenditure, a modest rate of convergence in government expenditure, and a slow rate of divergence in human capital (which influenced income more positively than the other determinants).

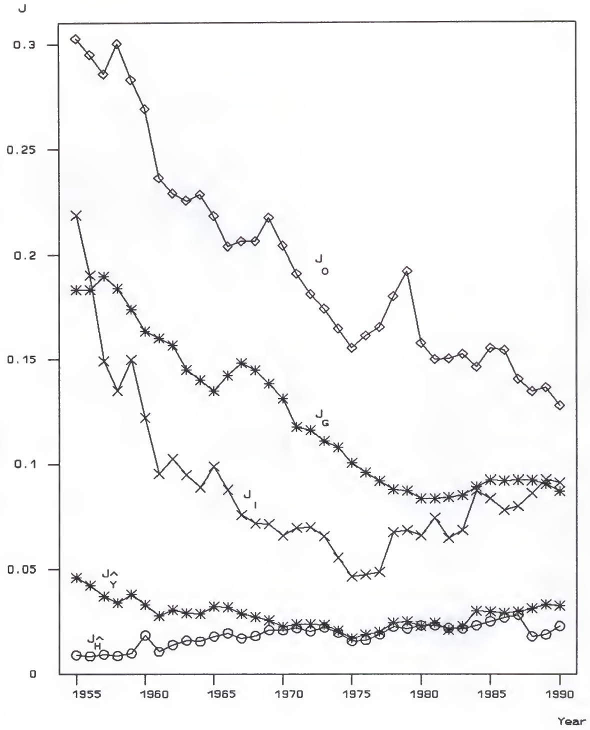


Figure 5.2 - Inequality in Estimated Income ($J_{\hat{Y}}$), Human Capital ($J_{\hat{H}}$), International Openness (J_O), Investment (J_I) and Government (J_G) Expenditures in 22 OECD Countries, 1955-1990

5.7 Summary

From Section 5.4, the declining income inequality (observed and estimated) indicates that the countries in the OECD group are growing closer together in income. This evidence is in favor of the convergence component of the "extended" Kuznets' hypothesis. The slow rate of convergence in income could be attributed to the accelerated convergence in terms of openness offset by divergence in terms of investment expenditure and low rate of convergence in terms of human capital. Barro (1991) concluded that convergence in the OECD countries was clearly evident since these countries had high levels of per capita income and were similar in terms of economic and political institutions. Adding to this conclusion, this study showed that convergence in these countries was also a result of the influence of increasing levels of human capital and international openness. An attempt was also made to analyze the change in inequality using a time-differential to the Theil index (Appendix F). However, the results from the analysis of the time-differential were inconclusive for the purposes of this study.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Simon Kuznets (1955) hypothesized that, as an agrarian society becomes more urbanized and affluent, income inequality initially increases and then decreases (divergence followed by convergence). It is true that Kuznets discusses inequality within one country, not across countries, but several authors have extended the convergence-divergence hypothesis to the cross-country level. For example, Paukert (1973), Ahluwalia (1976), Papanek and Kyn (1986), Ram(1989), Theil (1989), Theil and Deepak (1993a,1993b, 1993c, and 1994), Seale et al (1994), Moss et al (1993), and Theil and Seale (1994) have used cross-country time-series data to test Kuznets' divergence-convergence hypothesis. The evidence from these studies suggests that rich countries are converging in terms of income and the countries with higher levels of human capital tend to converge faster. However, in most cases the analysis was based on either an inequality index or theories of economic growth, the exception being Weatherspoon who performed cointegration analysis on inequalities in income, investment and government expenditures, and industrial employment.

The objective of this study was to expand on research by Barro (1991) and Weatherspoon (1993) by including indicators for international trade and human capital into the analysis. While Barro used school enrollment ratios as a proxy for human

capital, this study used a multiple indicator, constituted by per capita levels of public expenditure on education, consumption of newsprint, and shares of population with secondary school and university education, for measuring human capital. Further, this study used the Theil inequality index to analyze convergence in the OECD countries and Barro used the relationship between growth rates and levels of income and human capital. This study also differed from Weatherspoon's in terms of methodology. While Weatherspoon used cointegration analysis, this study used a latent variable approach to analyze the effect, if any, of four factors of economic growth: human capital, international openness, investment and government expenditures on income convergence.

Income was estimated as a function of human capital, investment expenditure, government expenditure, and international openness drawing upon the theoretical underpinnings from standard macroeconomic theory and from recent developments in the theory of human capital accumulation. The scope of the study was to cover 22 OECD countries. The OECD countries were chosen based on the existing evidence of income convergence and the availability of relevant data for these countries.

Estimating income as a function of human capital prompted the use of a latent variable model since human capital was not a directly observable variable. The classical econometric treatment assumes that the observed variables are measured without error. Latent variable models incorporate measurement error in the observed variables into the process of estimation. Cointegration analysis requires time-series data over long periods of time and thus was not a very feasible methodology for this study.

Tallman and Wang (1992) reviewed neoclassical and endogenous growth theories and concluded that higher levels of education could positively influence the accumulation of human capital and thus the standard of living in an economy. Lucas (1993) concluded that countries with high rates of human capital accumulation could sustain greater rates of growth. Barro (1991) deduced that growth in income converged faster at higher levels of human capital. This study used public expenditure on education, consumption of newsprint, education at high school and university levels as observable variables for human capital. All these factors contribute positively to accumulation of human capital.

The latent variable model was estimated using maximum likelihood and the estimated values of the four factors of growth were obtained using Bartlett's method (1938). The results from estimation showed that the data fit the model reasonably well and that income and its determinants were growing over time. Therefore, the factors of growth specified for this study did appear to contribute to growth in income. These results comply with contemporary evidence (Barro, 1991; Mankiw et al., 1992).

Theil's inequality index was then used to measure observed and estimated inequalities for the OECD countries. The evidence from the inequality analysis was in favor of the convergence component of Kuznets' hypothesis for income, international openness, and government expenditures and favors the divergence component in terms of human capital and investment expenditure. These results suggested that the OECD countries were growing closer together in terms of income, international openness, and government expenditure and moving away in terms of human capital and investment

expenditure. Further, the inequalities in the determinants were slowing down the rate of convergence in terms of income for these countries.

Thus, the results from this study present an encouraging picture for ongoing research in this area of international economics. A multiple indicator for the level of human capital variable had not been previously estimated. Though international openness was also a good candidate for being measured as a latent variable, the lack of theoretical and quantifiable information on feasible indicators or proxies for this variable prompted its use as an observable variable for the purposes of this study. Though data are scarce, reliable and lengthy information on investments in research and development, science and technology, women's education and development, and health and environmental care over time and across countries, along with factors for international openness, may provide opportunities to further extend what has been accomplished in this study.

APPENDIX A

SEVEN REGIONS OF THE WORLD

The 22 countries in the **North** include USA, Canada, Japan, South Korea, and 18 European countries: Austria, Belgium, Denmark, Finland, France, Germany (W), Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK. The six countries in the **South** are Australia, New Zealand, Chile, Argentina, Uruguay, and South africa. The 43 countries of **Tropical Africa** are Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zaire, Zambia, Zimbabwe. The 22 countries of **Tropical America** are Barbados, Bolivia, Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Surinam, Trinidad and Tobago, Venezuela. The six countries of **South-West Asia** are Iran, Iraq, Israel, Jordan, Syria, Turkey. The six countries of **South-Central Asia** are Bangladesh, India, Myanmar, Nepal, Pakistan, Sri Lanka. The eight countries of **South-East Asia** are Hong Kong, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, Taiwan, Thailand.

APPENDIX B

EUROPE, AFRICA, AND SOUTHERN CONE

The first region constituting **Western Europe, Mediterranean Europe** and **Mediterranean Africa** consists of **Europe's core**: UK, France, Switzerland, Germany (W), and the three Benelux countries; 11 countries around the core: Austria, Denmark, Finland, Greece, Iceland, Ireland, Italy, Norway, Portugal, Spain, Sweden; countries of North Africa: Algeria, Egypt, Morocco, Tunisia. The second region constitutes **South Africa**: Chad, Mali, Mauritania, Niger, Sudan; and its Northern neighbors: Namibia, Botswana, Zimbabwe, Swaziland, Mozambique, Angola, Zambia, Malawi, Tanzania. The third region constitutes USA, Mexico, and Central America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama). The fourth region constitutes the **Southern Cone** of South America: Argentina, Chile, Uruguay; and its Northern neighbors: Brazil, Bolivia, Paraguay, Peru.

APPENDIX C

WESTERN EUROPE

There are 18 countries constituting **Western Europe** which is divide into three regions. One is **non-EU**, consisting of six countries: Austria, Finland, Iceland, Norway, Sweden, Switzerland. Another is the **EU Center**, consisting of eight countries: Belgium, Denmark, France, Germany (W), Italy, Luxembourg, Netherlands, UK. The third is the **EU Periphery**, consisting of four countries: Greece, Ireland, Portugal, Spain.

APPENDIX D

WESTERN PACIFIC REGION

The **Western Pacific** region consists of 15 non-Communist countries: Australia, Fiji, Hong Kong, Indonesia, Japan, Malaysia, New Zealand, Papua New Guinea, Philippines, Singapore, Solomon Islands, South Korea, Taiwan, Thailand, Western Samoa.

APPENDIX E

FOUR REGIONS REVISITED

The 18 European countries in the **North** are Austria, Belgium, Denmark, Finland, France, Germany (W), Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK. The 37 countries of **Sub-Saharan Africa** are Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, Swaziland, Tanzania, Togo, Uganda, Zaire, Zambia, Zimbabwe. The five countries of **South-Central Asia** are Bangladesh, India, Myanmar, Pakistan, Sri Lanka. The eight countries of **South-East Asia** are Hong Kong, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, Taiwan, Thailand.

APPENDIX F

CHANGE IN INEQUALITY

A time-differential of Theil's inequality index is derived here that links changes in inequality to changes in income and population. If J is defined as in equation (5.1), then J can also be written as

$$
\begin{aligned}
J &= \sum_{i=1}^{n} p_i \ln(\frac{p_i}{y_i}) \\
&= k - \sum_{i=1}^{n} p_i \ln y_i \qquad\qquad \text{(F.1)} \\
&= k + \ln \sum_{j=1}^{n} N_j Z_j - \sum_{i=1}^{n} p_i \ln Z_i
\end{aligned}
$$

where Z_i is the GDP of country i. Taking partial derivatives with respect to Z_i we get

$$
\begin{aligned}
\frac{\partial J}{\partial Z_i} &= \frac{N_i}{\sum_{j=1}^{n} N_j Z_j} - \frac{p_i}{Z_i} \\
\frac{\partial J}{\partial Z_i} Z_i &= \frac{N_i Z_i}{\sum_{j=1}^{n} N_j Z_j} - p_i \qquad\qquad \text{(F.2)} \\
&= y_i - p_i
\end{aligned}
$$

which is the covariance of the population levels and income shares. Similarly, we derive another expression with respect to population shares

$$
\frac{\partial J}{\partial \ln N_i} = p_i \left(\frac{Z_i}{\bar{Z}} - 1 - \ln(\frac{Z_i}{\bar{Z}}) - J\right). \qquad \text{(F.3)}
$$

Therefore we finally arrive at an expression for dJ as

$$
\begin{aligned}
dJ &= \sum_{i=1}^{n} p_i \left(\frac{Z_i}{\bar{Z}} - 1\right) d(\ln Z_i) \\
&\quad + \sum_{i=1}^{n} p_i \left(\frac{Z_i}{\bar{Z}} - 1 - \ln \frac{Z_i}{\bar{Z}} - J\right) d(\ln N_i) \qquad \text{(F.4)}
\end{aligned}
$$

Writing this in time differential form we get

$$\Delta J_t = \sum_{i=1}^{n} (y_{it}^* - p_{it}^*)(DZ_{it} - \sum_{j=1}^{n} p_{jt}^* DZ_{jt}) + \sum_{i=1}^{n} [y_{it}^* - p_{it}^* - p_{it}^* (\ln \frac{y_{it}^*}{p_{it}^*} - J_t^*)] (DN_{it} - \sum_{j=1}^{n} p_{jt}^* DN_{jt}) \tag{F.5}$$

where

$$\begin{aligned} \Delta J_t &= J_t - J_{t-1} , \\ p_{it}^* &= \frac{1}{2} [p_{it} + p_{it-1}] , \\ y_{it}^* &= \frac{1}{2} [y_{it} + y_{it-1}] , \\ DZ_{it} &= \ln Z_{it} - \ln Z_{it-1} , \\ DN_{it} &= \ln N_{it} - \ln N_{it-1} , \\ J_t^* &= \sum_{i=1}^{n} p_{it}^* \ln \frac{p_{it}^*}{y_{it}^*} \end{aligned} \tag{F.6}$$

Therefore the change in income inequality can be written as

$$\Delta J_t = \sum_{i=1}^{n} (y_{it}^* - p_{it}^*)(DZ_{it} - \sum_{j=1}^{n} p_{jt}^* DZ_{jt}) + \sum_{i=1}^{n} (y_{it}^* - p_{it}^* - p_{it}^* (\ln (y_{it}^* / p_{it}^*) - J_t^*))(DN_{it} - \sum_{j=1}^{n} p_{it}^* DN_{jt}) \tag{F.7}$$

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Sri Devi Deepak of Hyderabad, India, completed her B.A. degree in mathematics, applied mathematics, and statistics at Osmania University, Hyderabad, in 1980. She received the National Merit Scholarship for graduate education for securing second rank in the B.A. examination. She completed her master's degree in business administration at Osmania University, Hyderabad, in 1982. Sri Devi worked as a Young Professional at Andhra Pradesh Industrial and Technical Consultancy Organisation, Hyderabad, India, for two years November 1982 to December 1984. Upon being selected via a national level examination, she served as an Assistant Development Officer in the National Bank for Agriculture and Rural Development (NABARD) for four years--two years at their Head Office in Bombay (December 1984 to January 1987) and two years at their Regional Office in Bangalore (January 1987 to March 1989). She came to the United States in April 1989 and commenced her doctoral program at the University of Florida in the Spring semester of 1990. Sri Devi has accepted a fellowship at Columbia Business School, New York, to pursue her second doctoral degree in Marketing starting Fall 1995.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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